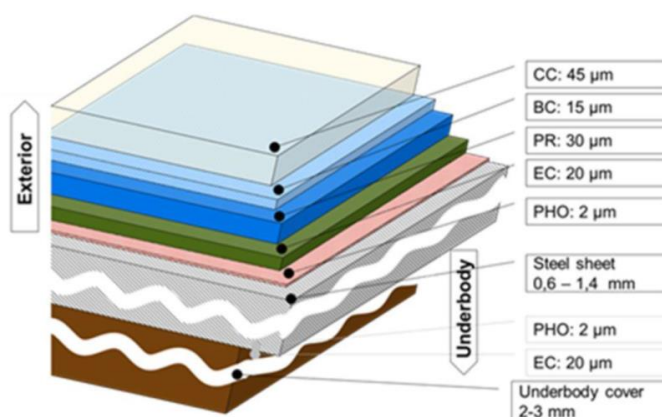


JRC SCIENCE FOR POLICY REPORT

# Best Available Techniques (BAT) Reference Document on Surface Treatment using Organic Solvents

*Industrial Emissions Directive  
2010/75/EU  
(Integrated Pollution  
Prevention and Control)*

Draft 1 – (October 2017)



*This draft has not been adopted or endorsed by the European Commission. Any views expressed are the preliminary views of the Commission services and may not in any circumstances be regarded as stating an official position of the Commission. The information transmitted is intended only for the Member State or entity to which it is addressed for discussions and may contain confidential and/or privileged material*

WORKING DRAFT IN PROGRESS

This document is one of a series of foreseen documents as below (at the time of writing, not all documents have been finalised):

<b>Reference Document on Best Available Techniques</b>	<b>Code</b>
Ceramic Manufacturing Industry	CER
Common Waste Gas Treatment in the Chemical Sector	WGC
Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector	CWW
Emissions from Storage	EFS
Energy Efficiency	ENE
Ferrous Metals Processing Industry	FMP
Food, Drink and Milk Industries	FDM
Industrial Cooling Systems	ICS
Intensive Rearing of Poultry and Pigs	IRPP
Iron and Steel Production	IS
Large Combustion Plants	LCP
Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilisers	LVIC-AAF
Large Volume Inorganic Chemicals – Solids and Others industry	LVIC-S
Large Volume Organic Chemical Industry	LVOC
Management of Tailings and Waste-rock in Mining Activities	MTWR
Manufacture of Glass	GLS
Manufacture of Organic Fine Chemicals	OFC
<i>Non-ferrous Metals Industries</i>	<i>NFM</i>
Production of Cement, Lime and Magnesium Oxide	CLM
Production of Chlor-alkali	CAK
Production of Polymers	POL
Production of Pulp, Paper and Board	PP
Production of Speciality Inorganic Chemicals	SIC
Refining of Mineral Oil and Gas	REF
Slaughterhouses and Animals By-products Industries	SA
Smitheries and Foundries Industry	SF
Surface Treatment of Metals and Plastics	STM
<i>Surface Treatment Using Organic Solvents including Wood Preservation with Chemicals</i>	STS
Tanning of Hides and Skins	TAN
Textiles Industry	TXT
Waste Incineration	WI
Waste Treatment	WT
Wood-based Panels Production	WBP
<b>Reference Document</b>	
Economics and Cross-media Effects	ECM
Monitoring of emissions from IED-installations	ROM

Electronic versions of draft and finalised documents are publically available and can be downloaded from <http://eippcb.jrc.ec.europa.eu/>

WORKING DRAFT IN PROGRESS

## PREFACE

### 1. Status of this document

Unless otherwise stated, references to “the Directive” in this document refer to Directive 2010/75/EU of the European Parliament and the Council on industrial emissions (integrated pollution prevention and control) (Recast). ~~means the Council Directive 96/61/EC on integrated pollution prevention and control. As the Directive applies without prejudice to Community provisions on health and safety at the workplace, so does this document.~~

This document is a working draft of the European IPPC Bureau (of the Commission's Joint Research Centre). It is not an official publication of the European Union and does not necessarily reflect the position of the European Commission

~~This document forms part of a series presenting the results of an exchange of information between EU Member States and industries concerned on best available technique (BAT), associated monitoring, and developments in them. It is published by the European Commission pursuant to Article 14(3) of the Directive, and must therefore be taken into account in accordance with Annex IV of the Directive when determining “best available techniques”.~~

### 2. Participants in the information exchange

As required in Article 13(3) of the Directive, the Commission has established a forum to promote the exchange of information, which is composed of representatives from Member States, the industries concerned and non-governmental organisations promoting environmental protection (Commission Decision of 16 May 2011 establishing a forum for the exchange of information pursuant to Article 13 of the Directive 2010/75/EU on industrial emissions (2011/C 146/03), OJ C 146, 17.05.2011, p. 3).

Forum members have nominated technical experts constituting the technical working group (TWG) that was the main source of information for drafting this document. The work of the TWG was led by the European IPPC Bureau (of the Commission's Joint Research Centre).

### 2. ~~Relevant legal obligations of the IPPC Directive and the definition of BAT~~

~~In order to help the reader understand the legal context in which this document has been drafted, some of the most relevant provisions of the IPPC Directive, including the definition of the term ‘best available techniques’, are described in this preface. This description is inevitably incomplete and is given for information only. It has no legal value and does not in any way alter or prejudice the actual provisions of the Directive.~~

~~The purpose of the Directive is to achieve integrated prevention and control of pollution arising from the activities listed in its Annex I, leading to a high level of protection of the environment as a whole. The legal basis of the Directive relates to environmental protection. Its implementation should also take account of other Community objectives such as the competitiveness of the Community’s industry thereby contributing to sustainable development.~~

~~More specifically, it provides for a permitting system for certain categories of industrial installations requiring both operators and regulators to take an integrated, overall look at the polluting and consuming potential of the installation. The overall aim of such an integrated approach must be to improve the management and control of industrial processes so as to ensure a high level of protection for the environment as a whole. Central to this approach is the general principle given in Article 3 that operators should take all appropriate preventative measures against pollution, in particular through the application of best available techniques enabling them to improve their environmental performance.~~

The term ‘best available techniques’ is defined in Article 2(11) of the Directive as ‘the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole.’ Article 2(11) goes on to clarify further this definition as follows:

‘techniques’ includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;

‘available’ techniques are those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;

‘best’ means most effective in achieving a high general level of protection of the environment as a whole.

Furthermore, Annex IV of the Directive contains a list of ‘considerations to be taken into account generally or in specific cases when determining best available techniques... bearing in mind the likely costs and benefits of a measure and the principles of precaution and prevention’. These considerations include the information published by the Commission pursuant to Article 16(2).

Competent authorities responsible for issuing permits are required to take account of the general principles set out in Article 3 when determining the conditions of the permit. These conditions must include emission limit values, supplemented or replaced where appropriate by equivalent parameters or technical measures. According to Article 9(4) of the Directive, these emission limit values, equivalent parameters and technical measures must, without prejudice to compliance with environmental quality standards, be based on the best available techniques, without prescribing the use of any technique or specific technology, but taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In all circumstances, the conditions of the permit must include provisions on the minimisation of long distance or transboundary pollution and must ensure a high level of protection for the environment as a whole.

Member States have the obligation, according to Article 11 of the Directive, to ensure that competent authorities follow or are informed of developments in best available techniques.

### 3. Structure and contents of this document

Chapter 1 provides general information on the surface treatment using organic solvents (STS) sector and on the Key Environmental Issues (KEI) for the activity.

Chapters 2 to 15 give general information, the applied processes, current emission and consumption levels and techniques to consider in the determination of BAT for the STS (including WPC) sectors that are covered by these chapters.

Chapter 16 provides thumbnail descriptions of additional STS sectors, for which a data collection via questionnaires has not been carried out.

Chapter 17 provides information on the common industrial processes, abatement systems and general techniques that are used across most of the sectors of the STS activity. The WPC-relevant techniques are described in Section 15.4.

Chapter 18 presents the BAT conclusions as defined in Article 3(12) of the Directive, both general and sector-specific for the two covered activities.

Chapter 19 presents the emerging techniques for the STS activity.

Chapter 20 contains the concluding remarks (to be updated on a later stage).

Chapter 21 contain the Annexes with valuable information not fitted into other chapters.

Chapters 2 to 16 provide the information given below on specific sectors (i.e. vehicle coating, coating of plastic workpieces and metal surfaces not described in other sections, coating of ships and yachts, coating of aircraft, coil coating, industries, manufacturing of adhesive tapes, coating of textiles, foils and paper, manufacturing of winding wire, coating and printing of metal packaging, heatset offset web printing, flexography and non-publication gravure, publication gravure, coating of furniture and wood material, wood preservation, manufacturing of mirrors and coated abrasives), using the following structure (X is the chapter number):

- Section X.1 provides general information on the sector.
- Section X.2 provides information on applied processes and techniques.
- Section X.3 provides data and information concerning the environmental performance of installations within the sector, in terms of current emissions, consumption and nature of raw materials, and use of energy.
- Section X.4 describes in more detail the techniques to prevent or, where this is not practicable, to reduce the environmental impact of operating installations in this sector that were considered in determining the BAT. This information includes, where relevant, the environmental performance levels (e.g. emission and consumption levels).

### **3. Objective of this document**

~~Article 16(2) of the Directive requires the Commission to organise ‘an exchange of information between Member States and the industries concerned on best available techniques, associated monitoring and developments in them’, and to publish the results of the exchange.~~

~~The purpose of the information exchange is given in recital 25 of the Directive, which states that ‘the development and exchange of information at Community level about best available techniques will help to redress the technological imbalances in the Community, will promote the worldwide dissemination of limit values and techniques used in the Community and will help the Member States in the efficient implementation of this Directive.’~~

~~The Commission (Environment DG) established an information exchange forum (IEF) to assist the work under Article 16(2) and a number of technical working groups have been established under the umbrella of the IEF. Both IEF and the technical working groups include representation from Member States and industry as required in Article 16(2).~~

~~The aim of this series of documents is to reflect accurately the exchange of information which has taken place as required by Article 16(2) and to provide reference information for the permitting authority to take into account when determining permit conditions. By providing relevant information concerning best available techniques, these documents should act as valuable tools to drive environmental performance.~~

### **4. Information sources**

This document is based on information collected from a number of sources, in particular through the TWG that was established specifically for the exchange of information under Article 13 of the Directive. The information has been collated and assessed by the European IPPC Bureau (of the Commission's Joint Research Centre) who led the work on determining

BAT, guided by the principles of technical expertise, transparency and neutrality. The work of the TWG and all other contributors is gratefully acknowledged.

The BAT conclusions have been established through an iterative process involving the following steps:

- identification of the key environmental issues for the STS and WPC Industries;
- examination of the techniques most relevant to address these key issues;
- identification of the best environmental performance levels, on the basis of the available data in the European Union and worldwide;
- examination of the conditions under which these environmental performance levels were achieved, such as costs, cross-media effects, and the main driving forces involved in the implementation of the techniques;
- selection of the best available techniques (BAT), their associated emission levels (and other environmental performance levels) and the associated monitoring for this sector according to Article 3(10) of, and Annex III to, the Directive.

Expert judgement by the European IPPC Bureau and the TWG has played a key role in each of these steps and the way in which the information is presented here.

Where available, economic data have been given together with the descriptions of the techniques presented in sections of *Techniques to consider in the determination of BAT*. These data give a rough indication of the magnitude of the costs and benefits. However, the actual costs and benefits of applying a technique may depend strongly on the specific situation of the installation concerned, which cannot be evaluated fully in this document. In the absence of data concerning costs, conclusions on the economic viability of techniques are drawn from observations on existing installations.

## 5. Review of BAT reference documents (BREFs)

BAT is a dynamic concept and so the review of BREFs is a continuing process. For example, new measures and techniques may emerge, science and technologies are continuously developing and new or emerging processes are being successfully introduced into the industries. In order to reflect such changes and their consequences for BAT, this document will be periodically reviewed and, if necessary, updated accordingly

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This document represents a summary of information collected from a number of sources, including in particular the expertise of the groups established to assist the Commission in its work, and verified by the Commission services. All contributions are gratefully acknowledged.

## ~~5. How to understand and use this document~~

~~The information provided in this document is intended to be used as an input to the determination of BAT in specific cases. When determining BAT and setting BAT-based permit~~



conditions, account should always be taken of the overall goal to achieve a high level of protection for the environment as a whole.

The rest of this section describes the type of information that is provided in each section of the document.

Chapter 1 provides general information on the industries or activities concerned. Chapters 2 through to 19 each consist of the four following sections:

1. general information on the industry or activity concerned
2. a description of the industrial processes used within this industry or activity
3. data and information concerning current consumption and emission levels reflecting the situation in existing installations at the time of writing
4. techniques to be considered for determining BAT as explained below for Chapter 16; however, the emphasis is on techniques or information specific to each individual industry or activity falling under the scope of this document.

Chapter 16 describes techniques for the reduction of consumption and emission reductions and other techniques that are considered to be most relevant for determining BAT and BAT-based permit conditions in more detail, and are relevant for all or most industries or activities concerned. This information includes information on the consumption and emission levels considered achievable by using the technique, the costs and the cross media issues associated with the technique, and the extent to which the technique is applicable to the wide range of installations falling under the scope of this document. This includes, for example, in which industry or activity the technique is currently applied and whether it is, or is not, applicable to other industries or activities, including new, existing, large or small installations. Techniques that are generally seen as obsolete are not included.

Chapter presents the techniques and the consumption and emission levels that are considered to be compatible with BAT in a general sense. Section sets out generic BAT applicable in all industries in this sector, and Section through to set out specific BAT for each industry to be used in conjunction with those in Section

The purpose is thus to provide general indications regarding the consumption and emission levels that can be considered as an appropriate reference point to assist in the determination of BAT-based permit conditions or for the establishment of general binding rules under Article 9(8). It should be stressed, however, that this document does not propose emission limit values. The determination of appropriate permit conditions will involve taking account of local, site-specific factors such as the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. In the case of existing installations, the economic and technical viability of upgrading them also needs to be taken into account. Even the single objective of ensuring a high level of protection for the environment as a whole will often involve making trade-off judgements between different types of environmental impact, and these judgements will often be influenced by local considerations.

Although an attempt is made to address some of these issues, it is not possible for them to be considered fully in this document. The techniques and levels presented in Chapter 21 will therefore not necessarily be appropriate for all installations. On the other hand, the obligation to ensure a high level of environmental protection including the minimisation of long distance or transboundary pollution implies that permit conditions cannot be set on the basis of purely local considerations. It is therefore of the utmost importance that the information contained in this document is fully taken into account by permitting authorities. The rest of this section describes the type of information that is provided in each section of the document.

Since the best available techniques change over time, this document will be reviewed and updated as appropriate. All comments and suggestions should be made to the European IPPC Bureau at the Institute for Prospective Technological Studies at the following address:

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### **Interface between the IPPC and the Solvents Emissions Directives**

The following presentation of the issues is related to the interface between Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations (Solvents Emissions Directive) and Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (IPPC Directive).

It should be noted that the ultimate interpretation of Community law is a matter for the European Court of Justice and therefore it cannot be excluded that interpretation by the Court may raise new issues in the future.

The Solvents Emissions Directive contains the following main explicit references to the IPPC Directive:

• Article 4 of the Solvents Emissions Directive requires that *'without prejudice to Directive 96/61/EC, Member States shall adopt the necessary measures to ensure that existing installations comply with Article 5, 8 and 9 no later than 31 October 2007'*. This makes clear that compliance with the conditions laid down in the Solvents Emissions Directive does not remove the obligation to operate in compliance with all the provisions of the IPPC Directive, including a permit containing emission limit values or equivalent parameters and technical measures determined according to the provisions of Article 9(4) or Article 9(8) of the latter. As presented in the standard BREF preface, a certain flexibility is anchored in the provisions of Article 9(4) of the IPPC Directive as well as in the definition of BAT. However, if stricter conditions, compared to the conditions of the Solvents Emissions Directive, are determined by a competent authority or through general binding rules to be necessary to fulfil the requirements of the IPPC Directive for a particular permit, these stricter conditions shall apply.

• Article 6 of the Solvents Emissions Directive provides for the possibility for Member States to define and implement national plans for reducing emissions from the activities and existing installations covered by that Directive excluding surface cleaning and dry cleaning. However, according to Article 6(1) of that Directive, *'a national plan may under no circumstances exempt an existing installation from the provisions laid down in Directive 96/61/EC'*. Therefore, even if an installation is covered by a national plan, it still needs to operate in compliance with all the provisions of the IPPC Directive, including a permit containing emission limit values or equivalent parameters and technical measures determined according to the provisions of Article 9(4) or Article 9(8) of the IPPC Directive.

The IPPC Directive has the following reference to other legislation and emission limit values:

• Article 18(2) states that: *In the absence of Community emission limit values defined pursuant to this Directive, the relevant emission limit values contained in the Directives referred to in Annex II and in other Community legislation shall be applied as minimum emission limit values pursuant to this Directive for the installations listed in Annex I.*

The Solvents Emissions Directive is not listed in the Annex II as it came into force after the IPPC Directive. However, it is clearly *'other Community legislation'* for the purposes of Article 18(2), and the emission limit values it contains are therefore the minimum emission limit values for this industry sector

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**Best Available Techniques Reference Document on  
Surface Treatment using Organic Solvents**

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## SCOPE

The scope of this document is based on Annex 1, 6.7 to Council Directive 96/61/EC of 24 September 1996 on Integrated Pollution Prevention and Control (the IPPC Directive):

The scope of this document covers the following activities specified in Annex I to Directive 201/75/EU:

- 6.7: Surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with an organic solvent consumption capacity of more than 150 kg per hour or more than 200 tonnes per year.
- 6.10: Preservation of wood and wood products with chemicals with a production capacity exceeding 75 m<sup>3</sup> per day other than exclusively treating against sapstain.

*Annex 1, 6.7:*

*'Installations for the surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with a consumption capacity of more than 150 kg per hour or more than 200 tonnes per year.'*

Information on the interpretation of certain issues raised by the implementation of the IPPC Directive will be found in the guidance documents being prepared by the Commission's services. Information on how some issues are addressed in relation to the Scope of this document is given below.

For the STS activity, this document does not address the following:

- Dressing, as no installations were identified;
- Waterproofing of textiles by means other than as a continuous film using solvents; printing; sizing and impregnation of textiles. These may be covered by the BREF reference document for the textiles industry;
- Production of wood-based panels, laminate boards and chipboard, as these use water-based resins;
- Conversion of rubber as it is not a surface treatment activity;
- Manufacturing of coating mixtures, paints, inks and adhesives, and pharmaceutical products as these are not surface treatment activities.

The sections of this document referring to the WPC activities cover the following processes and activities (if at least one of the relevant thresholds in IDE Annex I, 6.7 or 6.10 is exceeded):

- the preservation of wood and wood products using water-based preservatives, solvent-based preservatives and creosote;
- blue stain treatment for long-term protection of wood/wood products in service (e.g. window frame production);
- preservation of wood and wood products by supercritical CO<sub>2</sub> process.

Although chemical wood modification and hydrophobisation (e.g. using resins) are considered 'wood preservation with chemicals', the TWG concluded during the kick-off meeting not to cover these activities in this BREF as at that time the number of plants in the EU was considered too small to justify the effort of inclusion as a sector and, additionally, the capacity of these installations was believed to be below the IED Annex I Activity 6.10 threshold.

However, impregnation with hydrophobisation agents such as oils, waxes or silicon compounds for waterproofing is covered in this BREF.

This document covers all activities from the storage of raw materials to the storage of treated wood and wood products. However, it does not cover any mechanical wood processing prior to preservation treatment even if conducted on site.

This document additionally addresses the following activities which are considered activities directly associated to the main Annex I, Section 6.10 or 6.7 activity, even if the directly associated activity is not necessarily an Annex I activity itself:

- treatment of waste, especially waste contaminated with wood preservatives, taking place on the WPC site;
- treatment of waste water being treated (oil separators, etc.) before discharge.

This document does not address the following plants/activities:

- sap stain treatment, as no information was submitted and none of the plants that took part in the data collection applies sap stain treatment associated with the WPC activities;
- sap stain treatment using solvents, as no information was submitted and none of the plants that took part in the data collection applies sap stain treatment using solvents;
- activities exclusively treating against sap stain if no solvents are being used or the relevant thresholds for activity 6.7 are not exceeded;
- ammonia treatment;
- on-site combustion plants where the flue-gases are used to dry wood direct, as only one plant reported direct drying, but no information was submitted;
- on-site combustion plants (including engines) not generating hot gases for directly heated dryers, including where energy is used for steam generation, indirect heating or electricity generation only; combustion plants which are not process-integrated and > 50 MW aggregated are covered by the Large Combustion Plants (LCP) BREF [ REF ].

In order to avoid duplication of information in the BREFs, the WPC parts in this document contain information specific to the wood preservation sector. This means, in particular, that generally applicable information on the storage of chemicals and hazardous substances, cooling systems, energy efficiency, monitoring or economics and cross-media effects pertain to other relevant BREFs or JRC reference reports. General information may be found in these documents. Only general issues that require clarification or specification with regard to wood preservation are addressed in this document.

Reference documents which may be relevant for the sectors covered in this document are the following.

Reference document	Subject
Monitoring of Emissions from IED installations (ROM)	Monitoring of emissions to air and water
Emissions from Storage (EFS)	Storage, loading and unloading of materials in general
Economics and Cross-Media Effects (ECM)	Economics and cross-media effects of techniques
Energy Efficiency (ENE)	Energy efficiency
Waste Treatment (WT)	Waste treatment
Large Combustion Plants (LCP)	Combustion techniques

The scope of the BREF does not include matters that concern:

- off-site transport of raw materials or finished products;
- the quality assurance of products produced;

## Scope

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- the marketing and distribution of products.

The scope of the BREF does not include matters that only concern safety in the workplace or the safety of products because these matters are not covered by the Directive. They are discussed only where they affect matters within the scope of the Directive.

### Installation

'Installation' is defined in the IPPC Directive, Article 2.3, as: 'A stationary technical unit where one or more activities listed in Annex I (to the IPPC Directive) are carried out, and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution'.

### Organic solvents and VOC

Commercially used organic compounds are chemicals containing carbon [38, TWG, 2004]. The Solvent Emissions Directive [73, COM, 1999] defines organic solvent as: '*any VOC which is used alone or in combination with other agents, and without undergoing a chemical change, to dissolve raw materials, products or waste materials, or it is used as a cleaning agent, or as a dissolver, or as a dispersion medium, or as a viscosity adjuster, or as a plasticiser, or as a preservative.*'

Organic solvents can be classified by chemical structure. There are three main groups:

- oxygenated solvents such as:
  - alcohols
  - aldehydes
  - esters
  - ethers
  - glycol ethers and their esters
  - ketones
- hydrocarbon solvents:
  - aliphatics
  - aromatics
- halogenated solvents.

The definition of VOC in the Solvent Emissions Directive is: '*any organic compound having at 293.15 K a vapour pressure of 0.01 kPa or more, or having a corresponding volatility under the particular conditions of use.*' However, Art.3(k) of the NEC Directive [88, COM, 2001] reads: '*Volatile organic compounds' and 'VOC' mean all organic compounds arising from human activities, other than methane, which are capable of producing photochemical oxidants by reactions with nitrogen oxides in the presence of sunlight*'. Apart from these, more examples of different VOC definitions, in European and national legislation and guidelines, can be found. Commonly, two phrases are in use: NMVOC which stands for non methane VOC, and VOC. When the latter phrase is used, it is not always clear if methane is included or excluded. However, in this document, when considering consumption and emissions, VOC is usually used to mean NMVOC.

Industry asked for clarification of the definitions of 'organic solvents' and 'consumption capacity'. At the conclusion of the information exchange, it could be seen that the exchange had dealt with information on organic solvents being defined as VOCs (as defined in the Solvent Emissions Directive, Council Directive 1999/13/EC). It could equally be seen that, in determining conclusions on BAT, the exchange had focused on installations whose actual use of solvents exceeded the consumption capacity thresholds stated in the IPPC Directive (where the use in the activity included solvents recovered from waste gas emission abatement equipment). Interpretation of these capacity thresholds is discussed in the context of work carried out by DG

Environment to develop some guidance on the interpretation of certain provisions of the Directive.

### **Surface treatment**

Section 6.7 in Annex I to the IPPC Directive refers to the following surface treatments: painting, adhesive application, further coating processes, impregnating, waterproofing, printing and surface cleaning. However, the information exchange does not consider BAT for industries or those parts of industries that are widely held to operate below the consumption capacities of the IPPC Directive, Annex 1 (6.7). The following are considered in detail:

- ~~printing (by heatset web offset, flexography and packaging gravure, publication gravure)~~
- ~~painting and other coating activities (winding wires, cars, trucks, buses, trains, agricultural and construction equipment, ships and yachts, aircraft, other metal surfaces, metal coil, metal packaging, plastics, furniture, wood and mirrors)~~
- ~~waterproofing (by painting and wood preservation)~~
- ~~adhesive application (in the manufacture of abrasives and adhesive tapes)~~
- ~~cleaning and degreasing in conjunction with other surface treatment activities (see The boundary of this document with other BREFs, below)~~
- ~~preservation of wood.~~

The following were not included where they form part of the activities addressed in the BREFs for Textiles and Tanneries:

- ~~dressing~~
- ~~waterproofing~~
- ~~sizing.~~

The manufacture of coating preparations, paints, inks and adhesives, and solvent extraction and rubber conversion processes are not in the scope of Annex 1, Section 6.7 to the IPPC Directive. Wood treatment processes such as the manufacturing of chipboard, the lamination of particle and fibre board (e.g. with impregnated phenolic paper) were not included because they use water-based adhesives.

### **Surface cleaning**

Surface cleaning can have three different interpretations:

1. ~~Cleaning as the ‘core’ activity, i.e. the activity is predominantly cleaning.~~
2. ~~Cleaning where another surface treatment is the ‘core’ activity (i.e. a surface treatment activity described in Annex I, Section 6.7 to the IPPC Directive), i.e.:~~

- ~~cleaning of surfaces of substrates prior to surface treatment~~
- ~~cleaning of equipment.~~

In both these cases, the techniques have been included in the scope of this document as surface treatment or associated activities.

3. ~~Cleaning using solvents where surface treatment is not the main activity. For example, the cleaning of a vessel between batches during manufacture of a solvent based product such as paint. This is not considered as an associated activity to surface treatment and is therefore not considered to be in the scope of this document.~~

### **The boundary of this document with other BREFs**

Surface treatment using solvents is also sometimes addressed in other BREFs. Examples of these BREFs are:

## Scope

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- the tanning of hides and skins
- the textile finishing industry
- the pulp and paper manufacturing industry
- ferrous metal processing
- glass and mineral fibres
- the surface treatment of metals and plastics (cleaning and surface pretreatment).

These BREFs can be used to validate, compare and challenge the submitted information. Conclusions reflected in the other BREFs do not affect or restrict the conclusions in this document.

Additional techniques and supporting information can be found in other IPPC reference documents, in particular the CWW BREF<sup>1</sup>, the Storage BREF<sup>2</sup> and the Monitoring REF<sup>3</sup>. BAT conclusions in these documents have not been validated for solvent coating processes but where similar physical and/or chemical conditions exist and considering the economic viability, the conclusions may be applied in this sector.

There are examples of activities that fall into the scope of the BREF on the Surface Treatment of Metals and Plastics (STM) addressing category 2.6: '*Installations for the surface treatment of metals and plastic materials using an electrolytic or chemical process where the volume of the treatment vats exceeds 30 m<sup>3</sup>*', and also fall into the scope of this document. The choice on where to put information on the activities that fall into the scope of both BREFs or in one of the two is made for practical reasons and the data are referenced. Electrocoating (e coat) is addressed in this document.

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<sup>1</sup> The BAT reference document on the Waste Water and Waste Gas Management/Treatment in the Chemicals Sector 67 — EIPPCB (2003). "Reference document on Best Available Techniques in Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector", European Commission.

<sup>2</sup> The BAT reference document Emissions from Storage 91 — EIPPCB (2005). "Reference document on Best Available Techniques on Emissions from Storage".

<sup>3</sup> The reference document on the General Principles of Monitoring 113 — EIPPCB (2003). "Reference Document on the General Principles of Monitoring".

WORKING DRAFT IN PROGRESS



# 1 GENERAL INFORMATION ON SURFACE TREATMENT USING ORGANIC SOLVENTS

[78, TWG, 2005]

*This section to be updated at a later stage –TWG please provide additional information*

*Information on Wood Preservation using Chemicals is currently in Chapter 15*

Where this document refers to solvents, it means organic solvents (unless further clarification is given such as 'water-based', etc.).

## 1.1 Organic solvents and treating surfaces

Organic solvents are largely derived from the petroleum industry and made by established producers (although there are alternatives, such as vegetable oil esters). Five million tonnes of solvents are sold and used in Europe and by far the largest demand for solvents comes from the paint and coatings industry. However, this has decreased from about 46 % in 1998 to 27 % in 2003. This is probably already due to a large shift to water-based and powder technologies, where these are technically feasible. Of the remainder, 7 % are used in printing ink formulations and 4 % in adhesives formulations. It is not possible to provide a further breakdown of these figures, as solvents producers do not know, for example, which type of formulations the solvents are used in, or if they are used for cleaning, etc.

The historic solvents sales data show a marginal average growth of 0.1 % per year over the last 10 years, below GDP growth. Projections of future consumption estimate no growth. The declining trend over the last years is linked to:

- increasing environmental legislation;
- increased penetration of water-based or alternative technologies, where feasible;
- solvent recycling and more effective use of solvents.

Organic solvents are usually categorised into classes of products. The most important classes are:

- oxygenated solvents: this includes esters, ketones, alcohols and glycol ethers (and their acetate derivatives);
- hydrocarbon solvents: aromatic (e.g. toluene, xylene), aliphatic and paraffinic hydrocarbon solvents;
- chlorinated solvents (not included in these statistics).

Within the solvents family, there has been a tendency to move away from aromatic and white spirit types of solvents, and to use less volatile products (less combustible, less potential exposure, less VOC release) where possible.

The production of solvents directly involves about 10 000 jobs and a turnover of EUR 2 500 million to EUR 3 000 million. Solvent usage involves about 10 million jobs in more than 500 000 companies in the EU-25, most of which are SMEs representing a global turnover of about EUR 200 000 million.

In this IPPC IED sector, the industries described use solvents for a wide range of activities. They are used in cleaning the surfaces to be treated, as well as a carrier for the treatment (such as ink, paint, preservative, insulation, adhesive). The industries themselves use the treatments for one or a combination of:

- communication (printing);
- decoration;

- prevention of corrosion and/or decay of surface or product;
- product preservation and delivery (such as food and drink cans, food packaging, aerosol cans, toiletries, drums, etc.);
- the application of a layer with a special function (e.g. electrical insulation, abrasion, adhesion).

This chapter (Chapter 1) provides general information on all the industries or activities concerned. Chapters 2 through to 19 each address an industry in the sector and consist of the four following sections:

Section 1: general information on the industry or activity concerned;

Section 2: a description of the industrial processes used within this industry or activity;

Section 3: data and information concerning current consumption and emission levels reflecting the situation in existing installations at the time of writing;

Section 4: techniques to be considered for determining BAT as explained below for Chapter 20; however, the emphasis is on techniques or information specific to the individual industry or activity.

Chapter 16 describes general techniques for the reduction of consumption and emission reductions and other techniques that are considered to be most relevant for determining BAT and BAT based permit conditions in more detail, and are relevant for all or most industries or activities concerned.

Chapter is in two parts: Section sets out generic BAT applicable in all industries in this sector. Section through to set out specific BAT for each industry to be used in conjunction with those in Section.

Paragraph 5 of the Preface sets out more fully how to understand and use this document.

## 1.2 Key environmental issues

*This section to be further updated at a later stage – work in progress*

### 1.2.1 Overall

The STS coating industries have a major role to play in extending the life of metals, such as for automotive bodies, ships, aircraft and construction materials, as well as providing means of preserving and delivering food and other products in packaging. The main environmental issues relate to solvent emissions to air, water and soil, particulate emissions to air, energy usage, waste minimisation and management, and site condition on cessation of activities.

Because of the flammable nature of solvents, their potential impact on the health and safety of workers and often their offensive odours, they have been controlled and extracted from the processes for many years. The industry can also discharge particles from the processes, especially from spraying and sanding. The extraction, and where applied, treatment of solvents and particles uses large fans and other equipment that can be major sources of noise. Many installations also use production equipment that is inherently noisy. Solvents may be used not only in cleaning the substrates but also equipment, giving rise to wastes containing solvents which may need special management for recovery and disposal. The sector uses significant energy both in the production processes, but also in end-of-pipe waste gas collection and treatment. The following issues are crucial:

- minimisation of the consumption of raw materials and energy;
- minimisation of emissions by process design, management and maintenance and by waste gas treatment;
- assuring chemical safety and prevention of environmental accidents.

The measures to achieve better environmental performance are frequently complex and have to be assessed in respect to their potential impacts on workplace health and safety, on the quality of the product and other processes, the age and type of installation, as well as on the benefits to the environment as a whole. Best available techniques will be balanced against these criteria and therefore include changes within process units as well as end-of-pipe abatement techniques.

Sophisticated process control and treatment techniques play an important part in achieving improved environmental performance. However, competent operation, and regular maintenance and a desire for improvement are as essential as is the choice of technology, particularly in reducing fugitive and untreated emissions of VOCs. Important considerations therefore include good management and working practices, good process and site design, education of the workforce on environmental and process performance, workplace safety and accident prevention, and finally, monitoring of the process and environmental performance.

### 1.2.2 Solvents

Because of their properties and the quantities involved, solvents are the key materials of concern:

- VOCs react with NO<sub>x</sub> in the presence of sunlight to form ozone in the troposphere. This usually refers to NMVOC (non-methane volatile organic solvents).
- Halogenated solvents, their toxicity and their impact on reducing ozone in the stratosphere.
- Some solvents are toxic to aquatic organisms.
- some solvents are not readily biodegradable, so they have the potential to contaminate soils. Traditional solvents are not PBT (persistent, bioaccumulative, toxic) and none are vPvB (very persistent, very bioaccumulative). However, solvents can readily spread through soil

to groundwater, where there are limited or no mechanisms for their removal or breakdown. There are numerous reports of aquifers used for drinking water being contaminated by solvents (although not necessarily from these industries).

Surface treatment using solvents was the ~~third~~ second largest source of VOC emissions from EU-28 European IPPC industries in 2015, according to E-PRTR, see Figure 1.1

However, the register has a threshold for reporting only emissions greater than 100 tonnes released to air a year, so many installations with lower releases will not have reported.

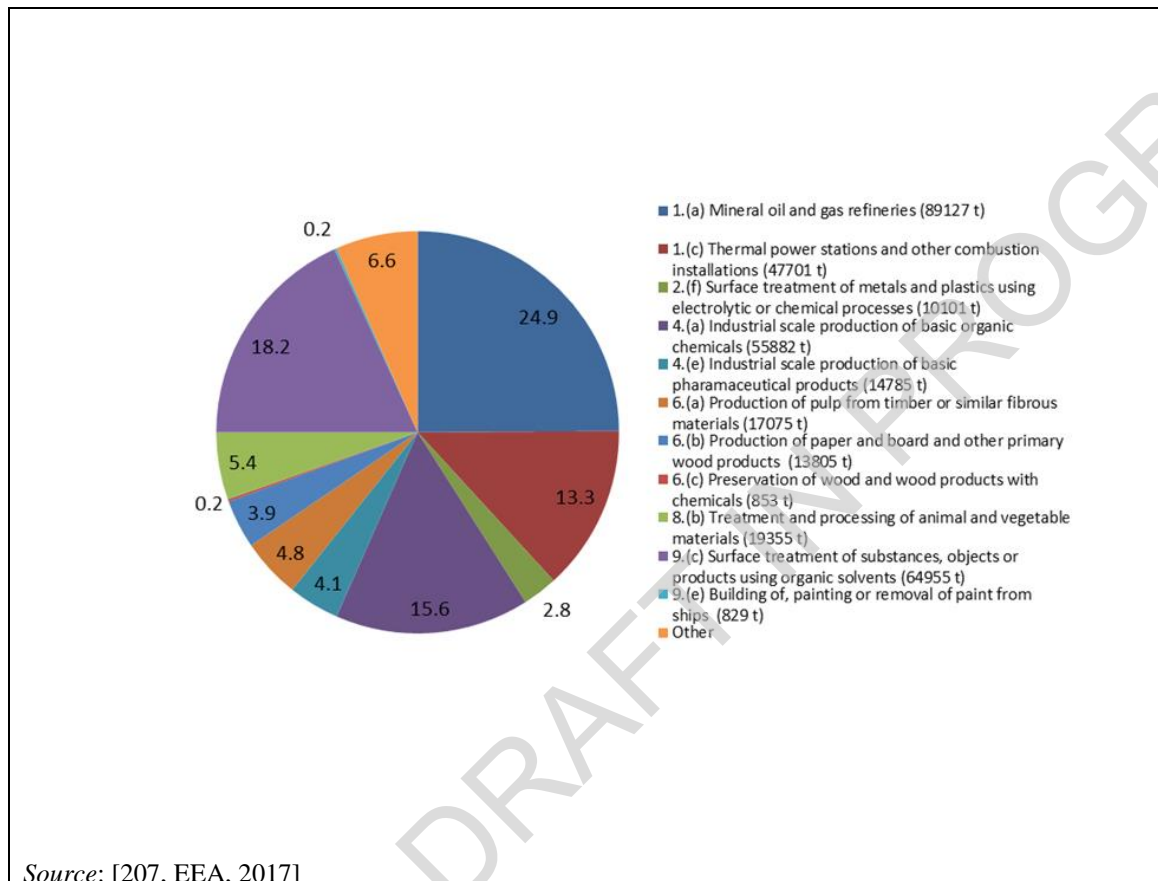


Figure 1.1: Non-methane volatile organic solvent emissions from IPPC processes for 2015

### 1.2.2.1 CMR solvents

The IED requires the replacement of substances or mixtures, which because of their content of VOC are classified as CMR, by less harmful substances within the shortest possible time. Most such solvents, particularly halogenated ones, have been replaced in industrial uses.

DMF (N,N-dimethylformamide) is used for the coating of textiles with polyurethane (PU) and in solvent mixtures when coating with polyvinylchloride (PVC) and this is discussed in Chapter 8.

### 1.2.3 Dust

These arise from some of the processes (such as sanding wood and other substrates) and from spray coating processes.

### 1.2.4 NO<sub>x</sub> and CO

NO<sub>x</sub> and CO emissions occur from thermal waste gas treatment techniques. They cannot be eliminated readily and in the STS industries their production is controlled by correct design of the waste gas treatment systems including low NO<sub>x</sub> burners and optimisation of the operating conditions.

### 1.2.5 Metals

Toxic metals such as cadmium lead, chromium and nickel are often referred to as occurring in water-based pretreatment and pigments for inks and paint. However, these have long been controlled by legislation such as Directive 76/769/EEC restricting the marketing and use of these and other pigments across the EU, the End of Life Vehicles Directive and the Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment, etc., and now under REACH. ~~They are not widely~~ Cadmium and lead are not used in large scale surface treatments using organic solvents and are not used by the printing processes discussed in detail in this document [51, COM, 1976] [52, COM, 2000] [53, COM, 2003].

Zinc and nickel (with manganese and iron) are used in phosphate conversion coatings in vehicle manufacture and other metal surfaces, to improve corrosion resistance and paint adhesion.

Water-based conversion coatings ~~passivation of~~ on zinc or zinc-alloy or phosphated surfaces ~~or aircraft bodies~~ prior to painting ~~is one~~ was a wide-spread use of hexavalent chromium (CrVI). This is discussed in the STM BREF [59, EIPPCB, 2006], together with its replacements. Due the End of Life Vehicles Directives, the use of Cr (VI) has ceased in vehicle coatings. To date, no alternative for the use of Cr(VI) conversion coatings on aircraft have been found and therefore currently none have type approval. Cr(VI) substances used in conversion coatings now have sunset date under the REACH Regulation [REACH 2006], of 21 September 2017, and as they are listed as Annex XIV substances will require specific authorisation for each use. *(To be updated - in progress)*

*There is now a REACH sunset date of Jan 22 2019 for various CrVI substances potentially used in paint pigments, some having slight solubility in water. The due date for applications for authorisation is July 22 2017. There are currently applications from about 10 manufacturers for CAS number 7789-06-2 (strontium chromate) for use in aerospace coatings and one for CAS 11103-86-9 for unspecified use in primers, sealers and coatings. *(To be updated - in progress)**

~~Organotin compounds and other toxic compounds~~ Dibutyl tin oxide is used as a catalyst in electrocoat paint systems for coating vehicles and other metal surfaces.

~~Copper, chromium and arsenic salts are used in water based wood preservation (see Chapter 15).~~

Small amounts of copper are used in copper phthalocyanine blue pigments for inks, but are not water-based. They are only periodically discharged and only found at background levels in effluents. The complex is strongly bound and not readily available.

### 1.2.6 Other pollutants

A key substitute for solvent-based coatings is the use of water-based coatings. These sometimes require biocides to stop them degrading in storage or use, or may have high COD and/or BOD from solubilisers, etc. which may have low biodegradability in some cases.

In the coating of ships, the removal of old, and the application of fresh, antifouling can give rise to contaminants such as TBTO (tributyl tin oxide) and other biocides. New types of antifouling are controlled by the IMO (see Chapter 4).

~~The preservation of wood uses toxic components in the treatment systems. Wood preservation accounted for about 30 % of EU 15 POP emissions in 1991, and although the use of POPs has decreased significantly, they are a factor in site decommissioning, in particular.~~

Ammonia is used as a stabiliser in some water-based solutions.

### **1.2.7 Energy**

All the industries are significant users of energy throughout the activities: in the surface treatment processes, in associated activities, and in the pollution abatement equipment. Significant amounts of energy are used to extract solvent contaminated air, and gas may be used as a support fuel for thermal destruction of VOCs at low concentrations. The balance of energy usage and VOC abatement must be carefully considered. In many cases, integrated solutions, such as better control of fugitive emissions and planned maintenance may abate significantly more VOC, in a more energy efficient way, than solutions based on waste gas treatment alone.

### **1.2.8 Raw material usage**

High efficiency techniques can be used to reduce material consumption generally. The emission of solvents can be significantly reduced by high efficiency application techniques and high solids coatings materials.

### **1.2.9 Water usage**

Water is used in cooling and in other processes, in particular water-based pretreatments and coatings. Minimising water consumption is important, and therefore dealt with in this document and in the STM BREF.

Important water-based pollutants for this sector are highlighted in Section 1.2.6.

### **1.2.10 Solid and liquid wastes**

Where solvents are used, the wastes generated may often be classified as hazardous. The proper storage and disposal of wastes is discussed.

### **Noise**

~~Many installations also use production equipment that is inherently noisy, such as folders and cutters in printing, metal presses and also because of the high production volumes and rates. These may be enclosed because of workplace health and safety. Waste gas extraction equipment relies on large fans which are a major source of noise, and some types of waste gas treatment are also noisy.~~

## 2 COATING OF VEHICLES

[13, DFIU and IFARE, 2002, 68, ACEA, 2004] [67, ACEA, 2005] [78, TWG, 2005] [142, ACEA, 2016] [146, ACEA, 2017] [170, OICA, 2017]

### 2.1 General information on the coating of vehicles

[142, ACEA, 2016] [146, ACEA, 2017] [170, OICA, 2017] [200, ACEA, 2016]

*This text replaces the text in the original BREF for the Sections 6.1 (Coating of cars), 7.1 (Coating of vans, trucks and truck cabs) and 8.1 (Coating of buses)*

#### 2.1.1 General

This section (2.1) gives a general introduction to the large scale coating of the vehicle types in Table 1 as classified by the automotive industry, [146, ACEA, 2017]. Not included in these data and also not covered in Chapter 2 are the coating of motorcycles, trailers, agricultural and construction equipment (these are covered if above the threshold<sup>1</sup> in Chapter 3, Plastic workpieces and metal surfaces not described in other sections).

**Table 2.1: Vehicle types**

Abbreviation	Vehicle type	Type Approval Category <sup>#</sup>	Terms used in this chapter
PC	Passenger Cars ( $\leq 9$ seats)	M1	PC, cars
LCV	Light Commercial Vehicles up to 3.5 t, (also called 'vans')	N1	Vans
MHCV (or CV)	Medium and Heavy Commercial Vehicles over 3.5 t, also called 'trucks'	N2 and N3	Trucks TC: truck chassis, CAB
BC	Buses and Coaches over 3.5 t and $> 8$ seats	M2 and M3	Buses

NB: Some LCVs (N1) are car-based and use similar paint processes to M1 and may be produced in the same installation.  
<sup>#</sup>The Type Approval Directive: Directive 2007/46/EC establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.

#### 2.1.2 Number, size and distribution of installations

There are 221 motor vehicle assembly plants in Europe (not including other separate plants for engine or components production, such as gearboxes, transmission) of which about 113<sup>4</sup> are covered by Annex 1, 6.7 of the IED. In some of the large vehicle manufacturing sites, in addition to vehicle coating, other painting activities are undertaken such as engine, bumper or wheel rim painting. These activities are covered in other chapters of this BREF (Chapter 3, Coating of plastic workpieces and metal surfaces).

<sup>4</sup> Figure from ACEA initial position information, 2015

Table 2.2: Motor vehicle production sites in the European Union (2015 data)

MS	Member State	PC	LCV	MHCV	BC	Factories
DE	Germany	24	5	4	2	41
FR	France	12	7	7	3	33
UK	United Kingdom	19	1	2	4	33
IT	Italy	10	5	3	1	23
PL	Poland	2	1	2	5	15
ES	Spain	9	5	2	1	14
NL	The Netherlands	4	1	3	2	10
SE	Sweden	3	-	2	2	9
BE	Belgium	3	-	4	2	8
CZ	Czech Republic	4	-	1	2	8
	Other Member States	14	2	6	2	27
EU	European Union	104	27	36	26	221

Source: [171, ACEA, 2016]

### 2.1.3 Geographic distribution

The motor vehicle production in the European Member States (EU) is concentrated in five countries which together represent 75 % of the total production.

Table 2.3: Production of motor vehicles in the EU in 2014

MS	Country	PC	LCV	MHCV	BC	Total	Share
DE	Germany	5 604 026	174 966	121 755	6 801	5 907 548	34 %
ES	Spain	1 898 342	477 097	27 539	0	2 402 978	14 %
FR	France	1 499 464	274 915	43 396	3 689	1 821 464	11 %
UK	United Kingdom	1 528 148	55 294	12 610	2 827	1 598 879	9 %
CZ	Czech Republic	1 128 473	0	821	3 893	1 133 187	7 %
Other MS		3 721 088	424 922	126 170	17 499	4 289 679	25 %
EU	European Union	15 379 541	1 407 193	332 292	34 709	17 153 735	100 %

Source: [170, OICA, 2017] Data for commercial vehicles are estimated to compensate for data gaps in the OICA statistics

### 2.1.4 Economic significance

The automobile industry is one of the major manufacturing industries in Europe and of international importance. It makes significant contributions to the EU economy in terms of GDP and trade balance, employment and industrial R&D and capital investment.



## GDP and trade balance

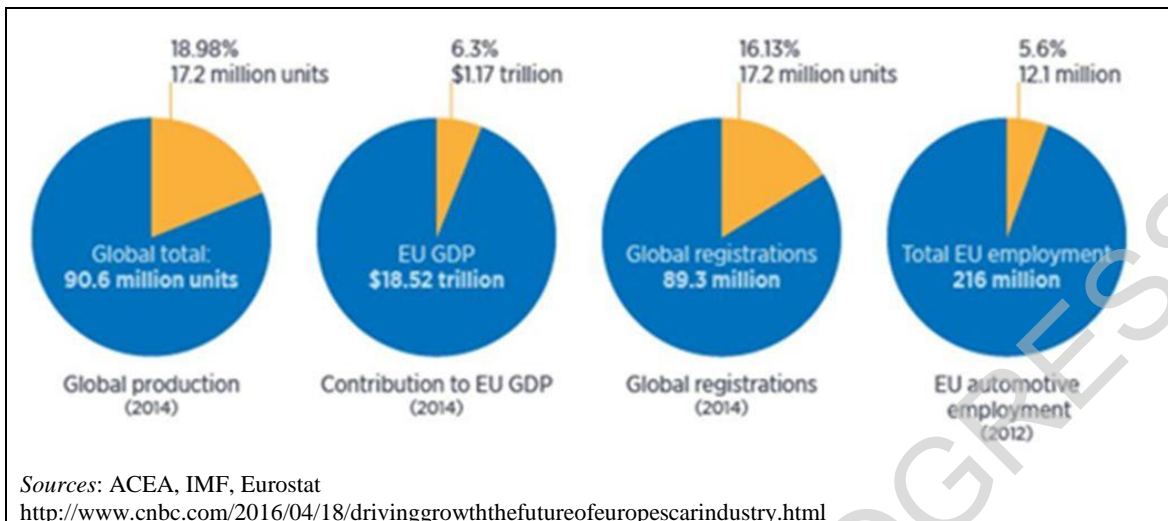


Figure 2.1: European automotive industry economic data

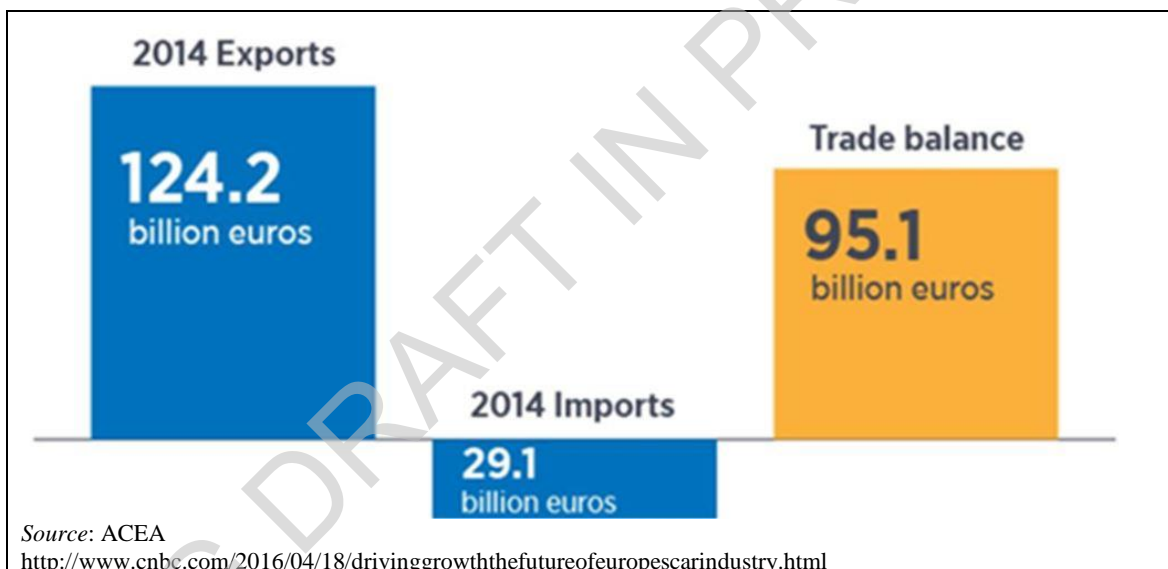


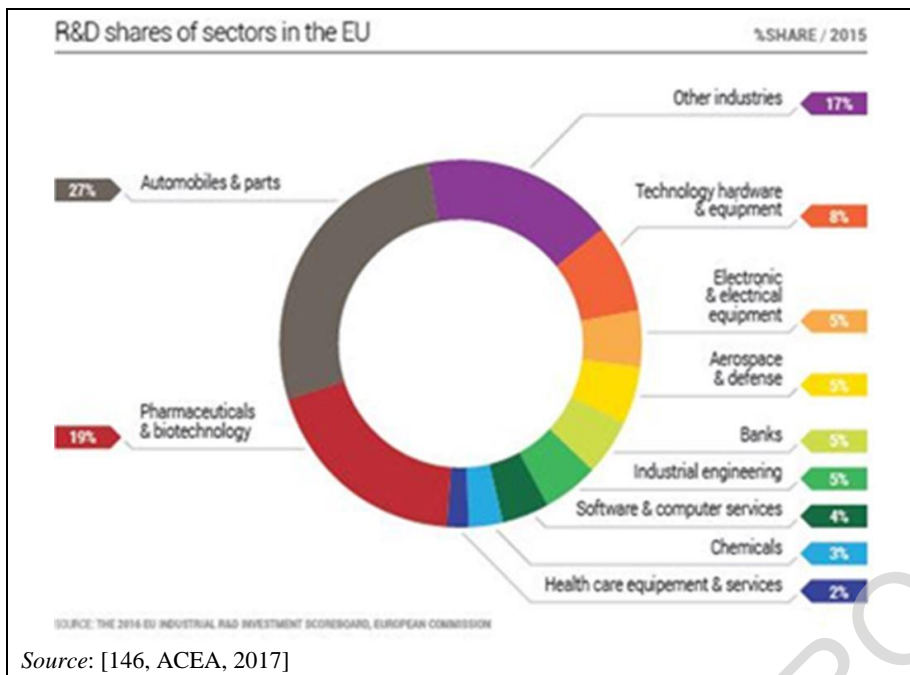
Figure 2.2: EU automotive industry balance of trade

### Employment

Almost 11 % of EU manufacturing employment is in the automotive sector: 2.5 million employed in direct manufacturing and 0.82 million employed in indirect manufacturing.

### R&D investment

The EU is the world's largest investor in automotive R&D and the automotive sector is the EU's biggest private investor in R&D, with EUR 50 128 million invested in 2015 (see Figure 2.3).



**Figure 2.3: EU Industrial R&D spend, 2015**

### Investment economics

Investment costs for a new passenger car paint shop range between EUR 150 million and EUR 500 million. Investment cycles are therefore a key factor for vehicle manufacturers. The optimal time to make environmental investments is when the renewal of equipment takes place within the normal investment cycle. Generally, major investment cannot be made in an existing installation, except when opportunities for major modifications of the paint shop facilities arise. These opportunities tend to occur after the normal lifetime of the paint shop (between 20 and 40 years) or when there is a step change in production volumes, which is often associated with a new product launch. Investment opportunities for new and existing installations are limited because the capital investment for building and equipment required is extremely high and ROI (return on investment) is low, giving long return on capital times. Investments are usually depreciated over 20 years.

The expense for a specific project depends very much on site-specific requirements (greenfield, brownfield), production capacity, availability of utility supply, and market situation. As a rule of thumb, due to demolition costs and integration into existing infrastructure, the replacement of spray booths / technical equipment or the extension of existing lines with additional equipment (such as waste air treatment systems) is 20 % to 40 % more expensive compared to greenfield projects.

On existing sites the implementation of a new paint shop will often lead to substantial downtimes in production because the very specific building requirements of the new paint shop (e.g. building ventilation, substantial foundations, free height under truss) also have to be implemented prior to the actual installation of the equipment

## 2.1.5 Key environmental issues

### 2.1.5.1 Water consumption

Long-term strategies, for reducing water consumption (including minimisation and recycling) have reduced the total<sup>5</sup> average consumption of water per car by 31.9 % between 2007 and 2016. This includes the application of recirculation strategies.

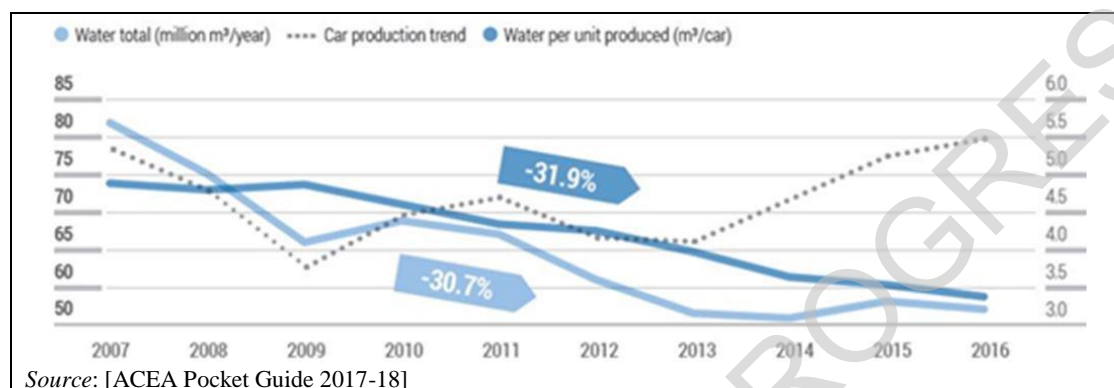


Figure 2.4: Water used in car production

Prior to painting, bodies and body components in white<sup>6</sup> are cleaned by aqueous alkali solutions of detergents. This is followed by pretreatment using aqueous solutions of zinc, manganese and nickel phosphates to ensure both reliable subsurface corrosion prevention and good paint adhesion.

In some cases, loads of zinc and nickel, as well as phosphate and fluoride from the same processes, exceed the E-PRTR reporting thresholds<sup>7</sup>. This is due to relatively high flow volumes (of the order of 200 000 m<sup>3</sup> a year) multiplying low emission values (usually well below ELVs).

### 2.1.5.2 Energy consumption

The complexity of cars has increased significantly, which has an effect on energy demand. Nevertheless, the industry has reduced the energy consumed per car by 12 % over the last decade. Of this, paint shops are about 30 % (based on 2012 data). Fluctuations in energy consumption can be explained by lower production volumes, especially during the economic crisis, as well as variable weather conditions in some years (see Figure 2.5).

<sup>5</sup> The water consumption applies to the total production usage, including production of car bodies as well as pretreatment activities of the bodies in paint shops.

<sup>6</sup> 'Body in white' refers to the bare metal body.

<sup>7</sup> Thresholds for release to water bodies or transfers to waste water treatment in Regulation (EC) No 166/2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC.

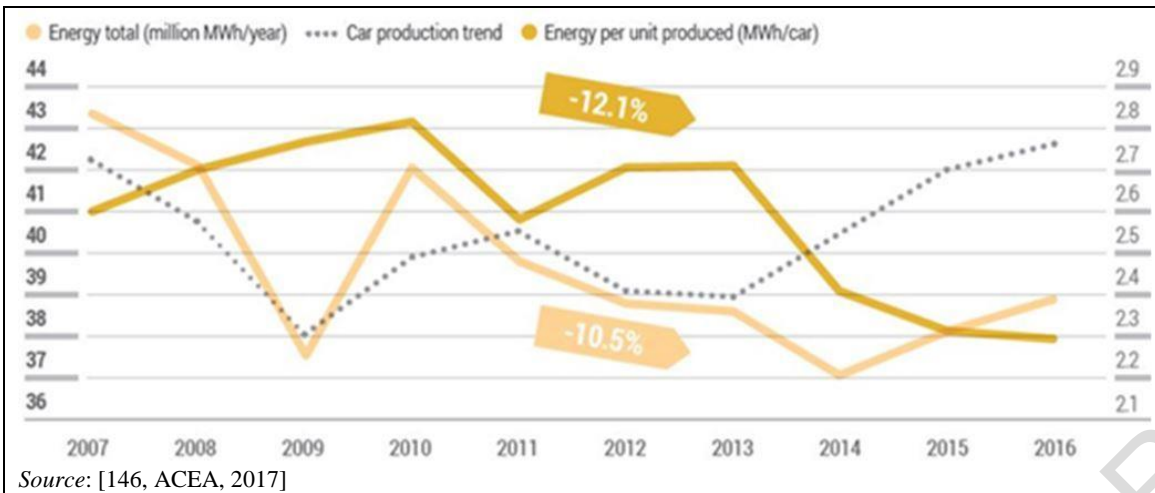


Figure 2.5: Energy consumption for the EU automotive industry

### 2.1.5.3 VOC emissions to air

The most important environmental issue related to the coating of new vehicles is the emission of VOC solvents mainly from paint shops. Figure 2.6 shows the evolution of VOC emissions per car produced and the total emissions of all car manufacturers combined. With new technologies, such as the replacement of solvent-based paints with solvent-free, water-based equivalents, manufactures have reduced unit emissions by 38.7 % per car over the last 10 years. This is likely to have been influenced by the implementation of the SED in 1999<sup>8</sup>, the exchange of information for the STS BREF (2004 to 2006) and the closure of older and less efficient sites during the 2008 economic crisis.

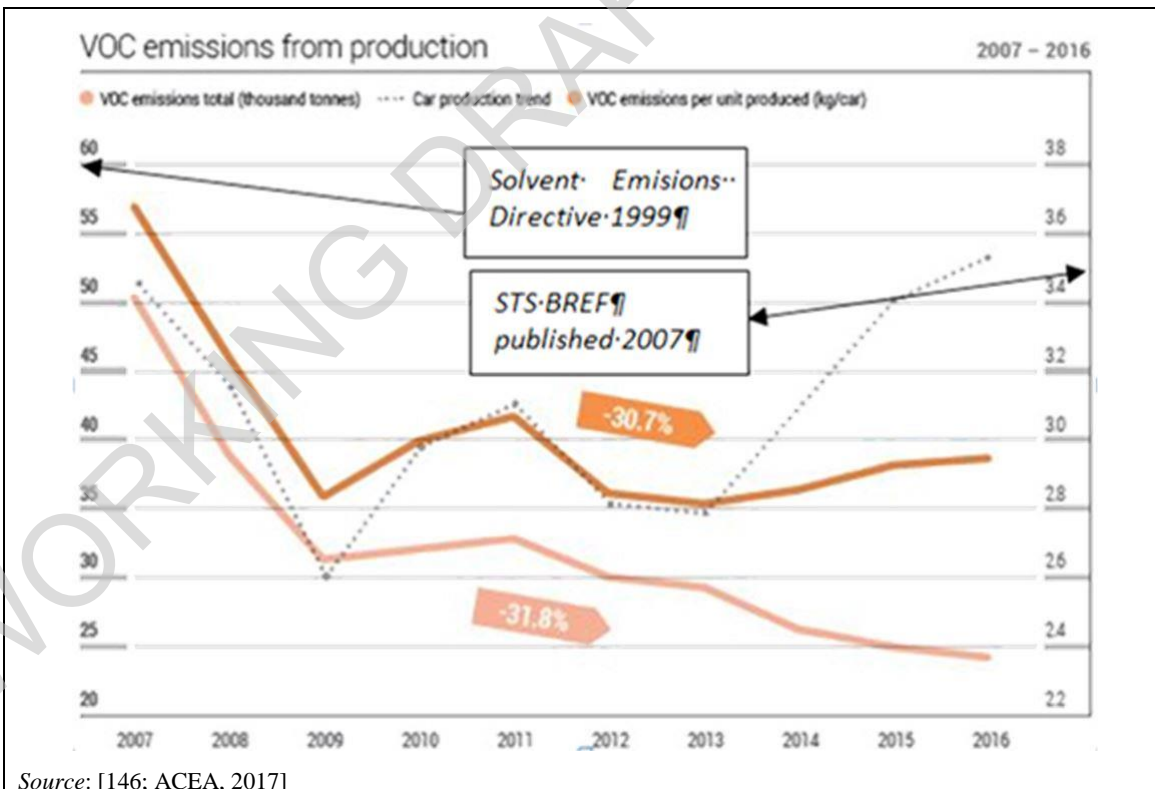


Figure 2.6: VOC emissions from the EU automotive industry

<sup>8</sup> Ref: Solvent Emissions Directive 1999.

### 2.1.5.4 Other emissions to air

Waste gas streams are treated for dry particles of paint overspray, while NO<sub>x</sub> and CO are emitted as combustion products of thermal waste gas treatments (see Table 2.4).

**Table 2.4: Air pollutants other than VOC from passenger car paint shops compared with EU-28 EMEP data**

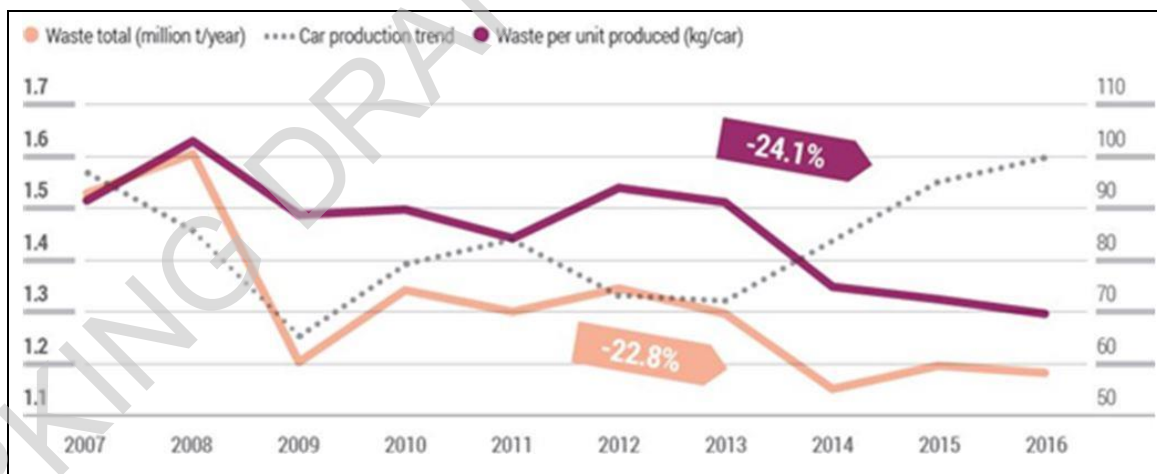
Pollutant	Specific emission from passenger car paint shops [kg/vehicle]	Total emission from all paint shops [Mg/yr]	EU-28 EMEP data [Gg/yr]	Paint shop share [%]
PM*	0.03	440#	1 934	0.025
NOX as NO2	0.11	1 610	8 459	0.019
CO	0.10	1 460	22 046	0.007

### 2.1.5.5 Waste generation

Figure 2.7 shows the trend in waste generation for complete cars (note: specific data on waste generation from the coating activities are presented in the data in Section 2.3.2.4). The waste generated per unit produced by the manufacturing of passenger cars fell by 22.8 % over 10 years. Waste fluctuations, both in absolute and per unit terms, can be explained by the occurrence of singular events, such as a fall in total production during the economic crisis.

Please note that the following data refer to the waste production for the entire process of car production and not only for the paint shop.

*TWG: Please clarify the 'boundary' of car production.*



**Figure 2.7: Waste from passenger car production (excluding scrap and demolition waste)**

## 2.2 Applied processes and techniques for the coating of vehicles

[142, ACEA, 2016], [169, VDI, 2013] [201, ACEA, 2016]

***This Section replaces Sections 6.2 (Coating of cars), 7.2 (Coating of vans, trucks and truck cabs) and 8.2 (Coating of buses) in the original BREF***

### 2.2.1 General

This section briefly describes the current production process and the directly associated activities for the serial painting of cars, vans, truck cabs and chassis and buses. It also indicates the main integrated techniques applied for the prevention and reduction of emissions.

The information is primarily based on cars, as their coating covers the full range of applied processes and techniques. There are significant differences in the coating of commercial vehicles due to different body designs and sizes, lower production volumes, the different end uses, and therefore different quality and other customer criteria. These differences are explained in separate sections for vans (Section 2.2.5), trucks (chassis, Section 2.2.6) truck cabins (Section 2.2.7) and buses (Section 2.2.8).

### 2.2.2 Overview of paint shop investment, design and operation

Each manufacturer has its own company- or brand-specific priorities and targets for the various quality demands and customer expectations for passenger cars, vans, trucks or buses. However, there are other objectives to be met, such as shareholder expectations and legal requirements including environmental issues.

These factors all influence the 'company philosophies' about how to design and operate a paint shop, so both the technical layout of the installations and the chosen corrosion protection and paint systems vary. The timing of investments, costs, and differences between existing and new sites is discussed in Section 2.1.4. The choice of paint systems and paint shop type are crucial to the reduction of VOC emissions and energy usage and are a 20- to 40-year commitment. While some retrofitting and updating of technologies may be carried out, this has a more limited effect on emissions and consumption.

Vehicle paint shops are very complex technical installations and can be seen as belonging to three 'families' (see Section 2.2.4.8). The decision to invest in a particular family is irreversible until a paint shop is rebuilt. Note that not all techniques can be combined and not all techniques are interchangeable, as the choice of compatible techniques are limited within a particular family.

Vehicle manufacturers with installations of this size are large companies and (predominantly) multinational or part of multinational groups. Such companies have well-developed management systems to balance and integrate the competing objectives outlined above. Those that may have the most significant impacts on consumption and emissions from production are:

- capital and business planning;
- operational management including quality systems and maintenance;
- environmental management systems.

In paint shops for passenger cars, the process steps are carried out in sequential lines and each subprocess is applied in a separate section of a line. Standard line capacities are between 30 and 60 units per hour. Normally the number of shifts per day is varied (one, two, three) to adjust the

paint shop output to customer demand, rather than changing the line speed. If higher output is required, additional lines are operated in parallel.

Paint shops are large and complex installations. Together with workstations for body preparation, inspection sections, body and material storage areas, ventilation equipment, paint overspray scrubbers, WG incinerators, and staff and maintenance areas, the installation stretches over several floors with a total area of 70 000 m<sup>2</sup> to 100 000 m<sup>2</sup>. The total line length of these different production segments is about 1.5 km. The processing time of a body in the paint shop is between 6 and 11 hours.

The heart of the paint shop, the spray booths, are very large units with at least three floors and cabin lengths between 60 m and 90 m per subprocess. In order to implement such a spray booth, a free building height under truss of 14 m is required to accommodate the key elements of the booth (over-spray scrubber, application zone and plenum).

### 2.2.3 Terminology

The following abbreviations are used frequently in the sections relating to vehicle coating (in the order they occur).

Term	Meaning	Term	Meaning
PT	Pretreatment	TC	Topcoat
CLE	Cleaning	BC	Base coat
PHO	Phosphating	CC	Clear coat
EC	E-coat	FI	Finish rework
SD	Sealer and damper	CP	Cavity preservation
PR	Primer		

### 2.2.4 Coating of passenger cars

This chapter discusses the large-scale coating of new passenger cars, (category M1, see Section 2.2.1). Some N1 vehicles (vans), which are produced in the same installation, may be based on cars and use similar production techniques.



Source: [© Volkswagen AG, 2015; Daimler AG, 2014.]

**Figure 2.8:** Examples for passenger car bodies showing the spread from very large to very small car bodies

### 2.2.4.1 Raw materials, handling, storage and paint mixing room

The main production raw materials (apart from the vehicle bodies) are paints and other coating materials, solvents for viscosity adjustment and cleaning and other cleaning materials. Waste materials will also be stored and handled in a similar manner.

The materials are unloaded on specially designed logistics areas with chemical-resistant flooring. Storage rooms and the paint kitchen are ventilated and often air conditioned and equipped to prevent soil and groundwater contamination from spillages. Leakages will be detected by technical monitoring systems and manual control routines.

### 2.2.4.2 Standard coating process

The following requirements have to be fulfilled by the coated car bodies and, therefore, by the paints:

- long-term protection against corrosion, weather, chemical influence (e.g. bird droppings, acid rain), chipping, sun, abrasion in car washes;
- ideal optical surface properties: polish, colour depth, free of cloudiness, faultlessness, therefore producing homogeneity and a consistency in colouring and formation of effects (such as metallic finishes).

These high requirements can only be achieved by at least three, often four or even five, paint layers designed to complement each other (see Figure 2.9). They are applied in several successive steps.

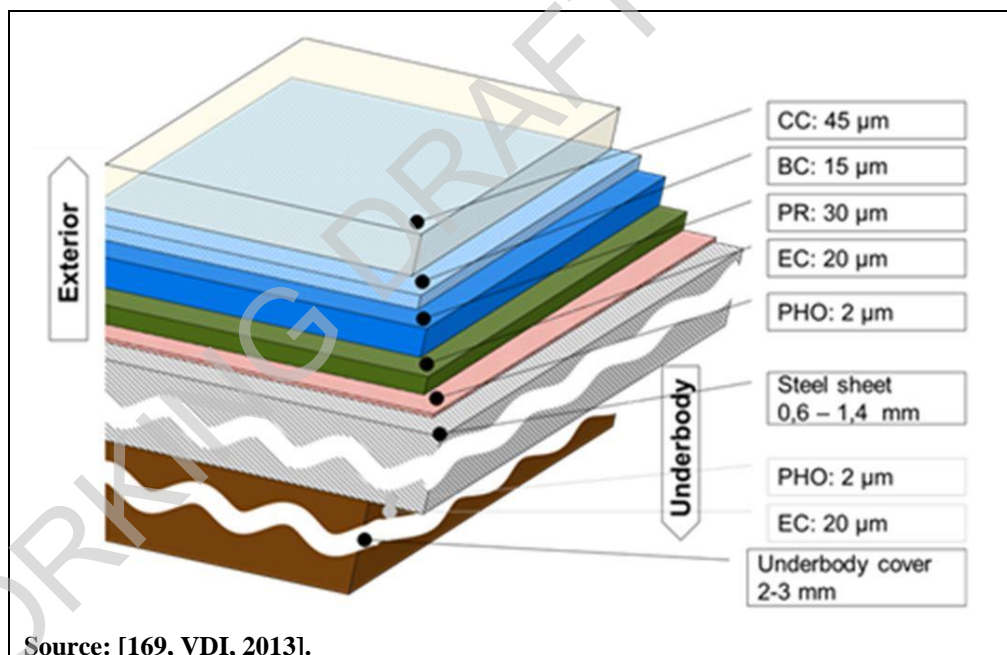


Figure 2.9: Layer sequence and typical thickness of passenger car coatings

A typical process flow is shown in Figure 2.10 and described in the paragraphs below. The abbreviations refer to stages shown in Figure 2.10.



### 2.2.4.2.1 Aqueous pretreatments and e-coat

The following pretreatment and e-coating activities are water-based and operate together with techniques that aim to prolong the usability of treatment or rinsing baths, minimise water consumption, optimise materials usage and minimise discharges to water. In many cases, waste water treatment is carried out in a separate treatment plant where waste water from other manufacturing activities is treated together with paint shop waste water. The aqueous pretreatments and associated techniques, together with the relevant waste water treatments, are described in the STM BREF. [8]

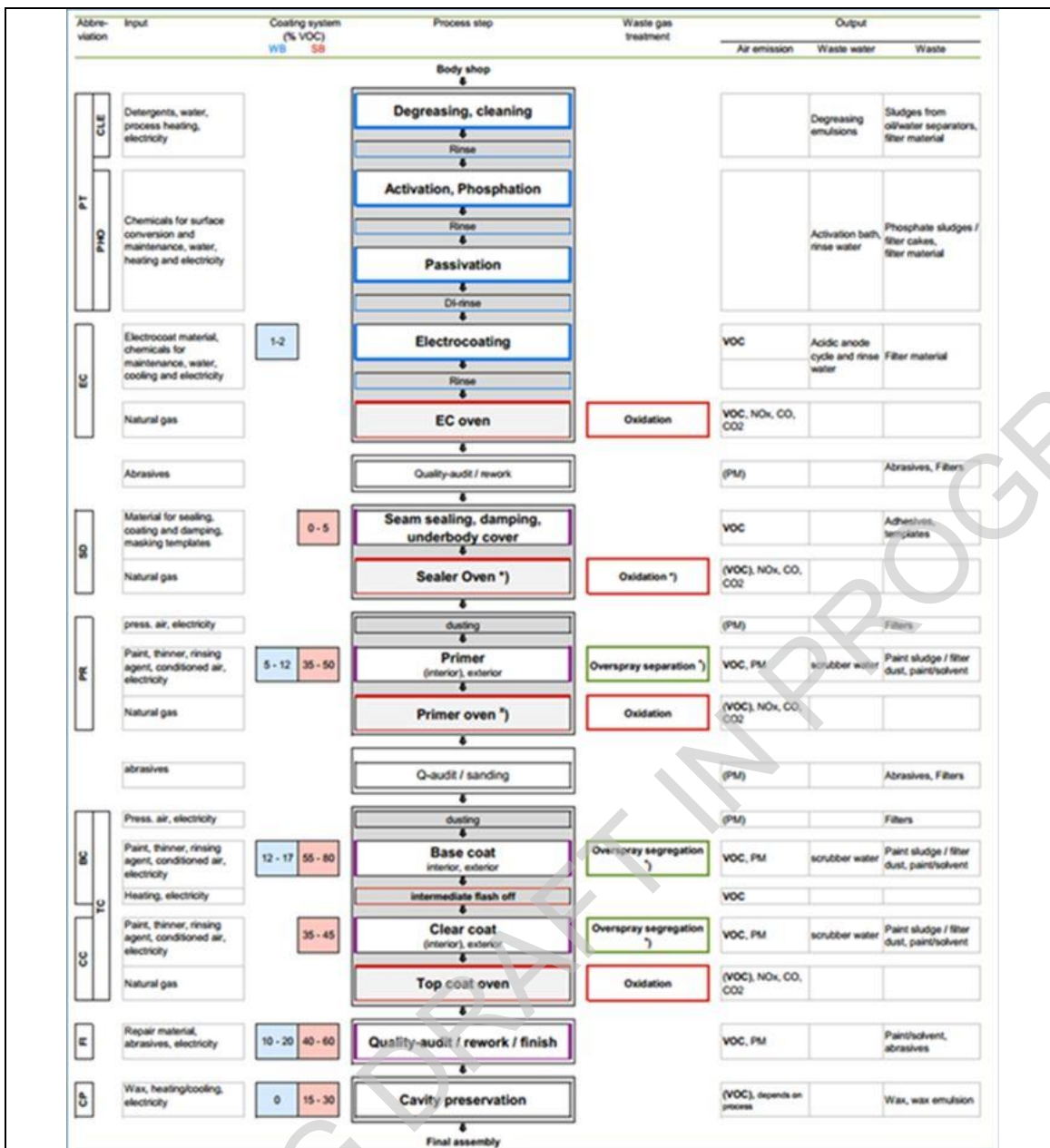
The bodies pass through the pretreatment and e-coat stages by conveyor systems. With pendulum or rotation conveyors, the bodies can be rotated and turned upside down in the treatment and rinsing tanks, to ensure all possible surfaces are treated.

#### **Pretreatment (PT)**

This consists of cleaning and degreasing, and phosphating.

#### **Cleaning and degreasing (CLE)**

From the body welding shop lines, the metal body in white is delivered to the pretreatment (PT-CLE) segment of the paint shop where weld dust, dirt, oil, grease, and adhesive residues from the stamping, welding, bonding, and grinding operations are removed in the spray and dip cleaning stations. Cleaning agents are aqueous alkaline detergent solutions which are applied at elevated temperatures (40–60 °C), followed by cascading rinse baths. Currently, demulsifying systems are generally used. These systems are fully described in the STM BREF [23, COM, 2006].



NB:

Main environmental impacts (consumption, emission) of the single subprocesses are included.

\*) Optional.

x) Not in paint shops with integrated processes.

+) In exceptional cases with additional VOC incineration. In some cases dry filter techniques are used instead of venturi scrubbers.

PT Pretreatment; CLE Cleaning and degreasing; PHO Phosphating; EC E-coat; SD Sealing and damping;

PR Primer; TC Topcoat; BC base coat; CC Clear coat; FI Finish (Rework); CP Cavity preservation.

Source: [201, ACEA, 2016]

Figure 2.10: Standard process flow for coating of passenger cars (PC)

### Phosphatation / Phosphate coating (PHO)

To improve corrosion resistance and enhance the adhesion of the subsequent organic coat, a phosphatation and passivation process is standard. The process solution with pH values between 2.8 and 3.8 contains phosphates of nickel, manganese, and zinc at temperatures between 35 °C and 55 °C. The passivation is usually carried out using zirconium salts<sup>9</sup>. Generally a two- or three-step cascade rinsing follows. As an alternative to phosphatation, nickel-free zirconium- or

<sup>9</sup> Chromium VI passivation is no longer used to comply with Directive 2000/53/EC on end-of-life-vehicles and (the 'ELV Directive') and REACH requirements.

silane-based treatments, which are applicable at room temperature, have been developed in the last 10 years. However, the process parameters of this type of pretreatment are much more delicate to control and the additional costs for these products are not compensated by the energy saving from the reduction of the process temperature. Most passenger car manufacturers have not yet approved these systems for pretreatment of multi-metal passenger car bodies.

### **E-coat (EC)**

E-coat (EC), short for cathodic electrodeposition, electrolytic coating or cathodic dip coating, is an immersion process where the pretreated body is moved through an aqueous coating. The coating delivers corrosion protection and is electrically deposited in an even film as substrate for the following spray applications. The organic coating is based on amine-modified epoxy resins which are made water-soluble through neutralisation with organic acids. The application concentrations are 16–20 % solids and 1–2 % organic solvents. The car body acts as cathode (negatively charged) and the anodes are positioned at the bottom and side walls of the tank. At high amperages, 5–10 kWh of energy per vehicle body is introduced into the EC bath and cooling is necessary to keep the bath temperature below 30 °C. The surplus coat is rinsed off from the car body. Paint particles which have not been electrically deposited are removed by rinsing with ultrafiltrate and deionised (DI) water (cascade). The e-coat film is then cured in a drying oven. Generally, the e-coat tank has a separate exhaust air system and in some installations the waste air from the e-coat cabin is conducted to the EC drying oven to remove the VOCs (see Section 2.2.4.5).

#### **2.2.4.2.2 Spray booths**

After drying the e-coat, the bodies continue to the spray booths where the primer, topcoat (base coat and clear coat) are applied. Seam sealants and damping materials are usually applied within the area of extracted air.

To remove dust and residues from the upstream body rework and preparation operations, the car bodies pass through ionised air blow-off stations, and/or are brushed with rotating emu feathers or robot-operated suction brushes and then transferred via airlocks to the spray booth.

Paint and solvents are generally stored in a separate room and pumped through ring lines to the spray cabins. Paint overspray is transferred with the downstream cabin air to particle filters or scrubbers which are placed below the open grating flooring of the paint cabin.

Spray coating needs closed booths and requires controlled booth-air conditions (the 'paint window', i.e. humidity, temperature and laminar downdraft). Compared to solvent-based paints, the paint window for water-based paints is smaller, which might cause higher energy consumption for cooling or dehumidifying in regions with extreme climatic conditions. A constant laminar downward air flow of 0.15 m/s to 0.4 m/s is necessary to ensure stable and reproducible application conditions in the immediate vicinity of the body surface and to transfer paint particle overspray to the particle separator systems under the paint booth. Additionally the air exchange rate must be high enough to keep the VOC concentration safely below the lower explosion limits (LELs) and in the case of manual application below the occupational exposure limits. Cabin air recirculation is therefore not allowed in combination with manual spray coating.

#### **2.2.4.2.3 Paint application**

##### **Automation**

Automation greatly improves the application efficiency, using less paint or sealer and therefore using and emitting less VOCs. Originally all paint operations were done manually using handheld spray guns with pneumatic atomisers. Today this is only done in European passenger car paint shops in special cases. From about 1980 to 2000, exterior painting was automated with

paint machines in the form of gantries, while interior coating and additional exterior painting remained manual. From 2000 to 2005, robots replaced painting machines and eliminated manual exterior painting. Robots were introduced in around 2010 to replace manual interior painting and this is ongoing.

### **Atomisation techniques and paint transfer**

There are different atomising techniques used to disperse the liquid paint and transfer the paint aerosol to the body surface. The optimisation of the paint transfer reduces paint and solvent usage, therefore reducing VOC emissions.

- Airless spraying where compressed paint is pumped through a spray nozzle. This is not widely used in serial coating of passenger cars.
- Air spraying or pneumatic spraying, in which a mixture of paint and pressurised air (sometimes at elevated temperature or with nitrogen instead of air) is forced through the paint nozzle and expands to a fine paint aerosol (pneumatic atomisation). In the automotive industry this concept is widely used with reduced air pressure as HVLP spraying (high-volume low-pressure).
- Pneumo-electrostatic guns may also be used, where the pneumatically atomised paint spray is electrically charged and attracted to a grounded body.
- High-speed rotational bell spraying with electrostatic charging is used in most vehicle paint shops.

If an electrostatic spray application with internal charging is used, paint supply systems with water-based paints need special electrical (galvanic) decoupling arrangements (e.g. cartridge systems). For water-based paints, external charging is commonly used.

The paint aerosol is transferred to the coating surface by its own particle momentum, in a directional air flow, along an electric field gradient, or a combination of these forces. By changing operational parameters, such as paint flow rate, bell rotation, voltage, and directional air flow, the shape of the spray jet can be adapted to the body surface and used for optimising the transfer efficiency. For painting of interior body parts, the electrostatic charging can be reduced or switched off.

### **Colour change and cleaning**

Reductions in paint waste and solvent emissions from cleaning are achieved by optimisation of paint colour supply and changing, and cleaning methods used.

In mass volume vehicle paint shops, paint is generally stored in a paint supply centre and pumped to the spray booths by steel ring lines, where each line is dedicated to one paint type and colour. Low-use colours are very often supplied from small paint distribution systems close to the booth. For base coat and primer (if more than one primer colour is used in the paint shop), these ring lines are connected to colour change devices for each single application unit (robot with one atomiser or paint machine with several atomisers). Colour changers are either placed at the side walls of the paint cabin or can be integrated at the final robot arm. Alternatively, separate paint cartridges are filled with paint (0.5–1.0 l) in a docking station and automatically docked to the application robot on demand. Several other systems are used.

Paint supply ring lines are only occasionally emptied and cleaned with solvent. Removed paint and cleaning agents are collected and disposed of as waste. Cleaning and colour change processes in the colour change devices and spray heads are more frequent and have more environmental relevance. Colour change includes (a) removing the old colour, (b) cleaning the supply system and (c) filling the new colour. For cleaning, either organic solvents or solvent-free cleaning liquids and/or pressurised air may be used. Spray guns, nozzles and the cones of paint bells are cleaned on demand. Used solvents are captured, and with paint residues from colour change and cleaning operations, generally collected and disposed of as waste.

To reduce paint losses, several different pigging and cleaning techniques have been developed in the last 20 years. They are used for cleaning and refilling the ring pipes or the atomiser feed line after the colour change switch.

### 2.2.4.3 Coatings

#### Sealing and damping (SD)

The highly viscose coatings for stone chip protection (generally PVC plastisols) and seam sealants are applied manually or with robots by several extruding techniques and airless spraying. In most cases, noise damping material either as custom-tailored pads or as extrudable paste is also applied in this section. The materials have very low VOC contents (2–5 %); nevertheless, the workplaces with high plastisol application are in cabins with enhanced ventilation.

Gelification (jellification/gelling) starts in the dedicated sealer oven and is ultimately completed in the next oven (primer or topcoat).

At some sites, materials for underbody and chip protection are applied at the final assembly section of the vehicle production facility.

#### Spray coating

Paints for spray coating are mixtures of organic resins with additives, organic or inorganic colour pigments (except for clear coat) and solvents, and are designed as one-component (1K) or two-component (2K) systems. For passenger cars, generally five different tones cover more than 90 % of the product volume (high runners) and the manufacturer's colour portfolio for a certain car model rarely exceeds 40 different colours. Primers are usually applied in two (maximum four) different tones fitted to the particular base coat colour.

Spray coating is done in three consecutive steps, primer, base coat and clear coat.

#### Primer (PR)

Primer provides for stone chip protection, avoidance of UV-induced decomposition of the underlying e-coat, and filling in of any small unevenness or rolling textures of the subsurface. Primer systems are based on polyester, melamine, and/or polyurethane resins. Coloured primers with up to four different tones are standard and help to reduce the thickness of the base coat. Primer systems are either solvent-based or water-based. Powder primers were used in some installations in Europe until 2015 when the last powder primer line was closed. The primer layer is cured after a preceding solvent flash-off in the primer oven. A quality check of the result of the upstream coating steps and manual rework of surface defects by sanding and sometimes recoating is done before the bodies enter the topcoat line.

#### Topcoat

This is made up of two layers: base coat (BC) and clear coat (CC).

#### Base coat (BC)

This layer determines the colour and effect (metallic, pearlescent) of the coat. Binder systems are polyester and melamine resins. In water-based coats, acrylates and polyurethanes are also used. Pigments might be either organic or inorganic (oxides of titanium or iron, silicates, aluminium flakes) and are free of heavy metals like lead, cadmium and chromium. Organic pigments may contain small amounts of copper or nickel bound in complexes or halogenated compounds. Both solvent-based and water-based systems exist in the automotive industry worldwide.

The wet paint is dried (but not cured) in a flash-off zone and then transferred to the clear coat zone. Some colours are applied without an additional clear coat as solvent-based one-layer top coats (monocoats).

The term 'effect colour' is used as an umbrella term for base coat systems with several special polychromatic effects like metallic, pearlescent, or colour flip effect. These systems are applied wet on wet in two or three steps and are always combined with a clear coat layer.

### **Clear coat (CC)**

The final paint layer is the clear coat which provides for high lustre and colour depth, optimum appearance, and chemical and scratch resistance. The chemical composition is based on a combination of acrylate and polyester resins. Usually solvent-based 2K systems are used with isocyanate hardeners added in a mixer as close to the spray system as possible.

The application of the clear coat is followed by a flash-off zone and subsequent top coat oven (also known as a clear coat oven).

Water-based 2K systems or 1K systems (either solvent-based or water-based) as well as powder clear coats or powder slurries are no longer in use in passenger car paint shops. *TWG: Please clarify*

### **Finish (Rework) (FI)**

A quality check and in-plant paint repair (if necessary) are carried out in special inspection zones and repair booths in what is generally called the finish zone. Materials used for these types of repairs are either paint repair systems (as used in retail repairs) or the same or similar paints as in the main line. Bodies with larger defects are sanded and (eventually, after masking the good parts) the whole body is put back into the top coat line (second run).

#### **2.2.4.4 Overspray separation**

Despite the improvements in automation and paint transfer techniques, some paint particles do not hit the vehicle body and are extracted with exhaust air. To minimise air pollution, various techniques are applied.

In existing installations, cross-flow venturi scrubbers are standard. In these systems, a vigorous mixing of cabin air and water droplets takes place at the venturi nozzle and the paint particles are transferred into the scrubber water. The paint particles are separated and managed as waste, and the water is recycled.

In recent greenfield installations and if paint lines in existing paint shops are completely rebuilt, alternative capture techniques are usually used:

- dry scrubbing with limestone: the paint adheres to limestone powder and is then separated using a rigid particle filter;
- electrostatic scrubbing (rinsed electric filter);
- cardboard box filters (for smaller installations);
- plastic dry filter systems (paint-stop filters) for spot repair and touch-up booths;
- classical water scrubbers.

### **Cavity preservation (CP)**

Additional corrosion protection of inner surfaces of cavities (which exist for constructional reasons) is delivered by a wax film. This coating can be carried out with two techniques:

- spraying, using wax solutions (solvent-based), wax emulsions (water-based) or 100 % wax (liquid pre-polymers that gel on contact with air);
- flooding the cavities with pure (100 %) heated wax.

#### 2.2.4.5 Drying

After the application of the paint systems, the wet paint film is dried in ovens. The following processes take place:

- physical drying, where the wet film solidifies because of evaporation of water and/or organic solvents;
- chemical cross-linking/reticulation (baking/curing) by polymerisation, polycondensation, polyaddition, or oxidative drying.

These processes start at room temperature immediately after mixing of the components or after application but a predefined curing temperature must be reached and maintained for sufficiently long to achieve a complete hardening of the coat.

Ovens are long tunnels with thermal isolation (60 m to more than 180 m in length). After the exit airlock, the car bodies pass through a cooling zone with outdoor air. Generally convection dryers are used, sometimes in combination with IR radiation sources. Dryers are heated with natural gas, and in many cases heat is recovered from recuperative oxidisers simultaneously working as incinerators of the VOC content of dryer waste air.

#### 2.2.4.6 VOC removal from waste air

VOC removal from waste air consumes large amounts of energy in extraction and treatment. It is generally applied to cleaning of exhaust air from dryers, because:

- most of the combustion energy can be used for heating the curing ovens (depending on the chosen design of the dryer-incinerator combination);
- of high raw gas concentrations (200–500 mg C<sub>tot</sub>/Nm<sup>3</sup>) in combination with low waste gas volumes (5 000–15 000 Nm<sup>3</sup>/h);
- it prevents the release of unpleasant smelling components (decomposition products from paint curing).

Typically, recuperative or regenerative thermal oxidisers are used, very often attached to the particular dryers as oven heating units. In some cases, an adsorption concentration step is included to increase the VOC concentration for the thermal waste air treatment.

#### 2.2.4.7 Waste management

Plant-specific waste management measures aim to reduce waste and to achieve a high recycling or recovery rate. This means reducing the waste produced during the coating activities, recycling where possible, separation of different kinds of wastes and sometimes it includes waste treatment processes like dewatering (paint sludge, phosphate sludge) or compacting (foils, packaging waste).

#### 2.2.4.8 Paint shop families

Depending on the type of solvents, paint systems are called (organic) solvent-based (SB), water-based (WB) or (no solvent) powder coats (PO). The term 'water-based paint' means that in the ready-for-use material a fraction (not necessarily 100 %) of the organic solvents is replaced by water. Relevant data for the most commonly used coats are presented in Table 2.5.

Table 2.5: Solvent contents of typical spray coats for passenger car coating

Coating	VOC content	Solids content	VOC/Solids ratio	Material consumption	Dry-film thickness
	%	%	/	kg/u	µm
SB primer	35–50	50–65	0.5–1.0	1.1–2.8	20–40
WB primer	5–12	45–55	0.1–0.26	1.2–2.4	20–40
SB medium solid (MS) base coat *	78–82 (60)	18–22 (40)	3.6–4.5	1.4–3.5	10–15 (25)
SB high solid (HS) base coat *	55–65 (50)	35–45 (50)	1.3–1.8	1.5–2.2	12–20 (25)
SB very high solid top coat (UHS-TC)	20–25	75–80	0.25–0.33	2.9–3.8	35–45
WB base coat *	12–17	16–22 (40)	0.6–1.0	2.3–3.5	10–15 (25)
WB top coat (MHTC)	18–22	45–50	0.36–0.49	1.9–2.1	35–45
SB 1K clear coat	40–50	50–60	0.66–1.00	2.0–3.0	40–45
SB high solid (HS) 2K clear coat	35–45	55–65	0.7–0.8	1.4–2.4	30–55

NB: \* Figure in brackets is for colours with low opacity.  
Source: [169,VDI, 2013]

Historically paint systems have been solvent-based with solvent contents up to 85 %, with a specific VOC emission of about 300 g/m<sup>2</sup>. Water-based coatings were developed in the late 1970s, with the aim of reducing the solvent emissions without the need to operate expensive and energy-consuming waste gas treatment systems. For some decades powder coats were used as primers and clear coats by some manufacturers, but these materials could not comply with the steadily rising quality demands and use finally stopped by 2015<sup>10</sup>.

Over time, two basic concepts of coating systems have emerged: solvent-based coatings (SB) and water-based coatings (WB). The choice of the coating system entails fundamental and mostly irreversible differences in the design of the paint shop, although at first sight the subprocesses are identical. Due to these differences in paint shop design, a change from solvent-based to water-based spray coats cannot be made without radical modification of the paint shop. Each combination of paint system, associated paint shop design, and paint application technique is called a 'paint shop family' and each individual paint shop belongs either to the WB or SB paint shop family.

Table 2.6: Technical differences between the paint shop families SB and WB

	SB	WB
Spray coating system:	Solvent based	Water based (except clear coat)
Intermediate dryer between base coat and clear coat	Short flash-off zone (not in all cases)	Intermediate dryer (with $T = 50 - 80$ °C, $t = 5 - 10$ min) and in/out air-locks necessary, typical length: 35 – 55 m (+ 75 % of total length of a top coat line). <sup>13</sup>
Primer dryer oven heating curve	No temperature hold below 100 °C necessary	5 – 10 min. temperature hold necessary to evaporate water before surpassing the boiling point temperature. <sup>14</sup>
Construction material for paint booths	Standard galvanised steel	Stainless steel for all parts in contact with paint
Use of electrically charged bells	Automatic application no restrictions	Automatic application Electrically disjoined paint supply system necessary which is slightly less efficient.
Paint window	Broader than for water based paints	Restrictions in range of humidity. Depending on local climate conditions additional equipment for air conditioning is necessary

Source: [143, ACEA 2017]

<sup>10</sup> The last powder primer line in the EU was stopped in 2015. Powder clear coat and powder slurry was replaced by solvent-based 2K HS systems between 2011 and 2013.



In existing sites, changing from one family to the other (SB to WB) can be done only if there is room to build a second paint shop (or paint shop line) in parallel without interrupting the production in the existing one, and where the new paint shop can be linked to the body shop and to the assembly shop. Due to these constraints such a transformation is very expensive and is rarely made. Where these changes are implemented, these are mostly restricted to one subprocess. This type of paint shop is then called a SB-MIX paint shop. The actual situation in the EU is shown in Table 2.7.

**Table 2.7: Estimated frequency of different paint shop families in the European Union**

Paint shop family	Subprocess			Installations	Process	Installations
	PR *	BC *	CC			
WB	WB	WB	SB	57 %	Standard	42 %
					Integrated	15 %
SB-MIX	WB SB	SB WB	SB	27.5 %	Standard	27 %
					Integrated	1.5 %
SB	SB	SB	SB	14.5 %	Standard	13 %
					Integrated	1,5 %
<b>Standard (all families)</b>						82 %
<b>Integrated (all families)</b>						18 %
* Different names and abbreviations are used for the various versions of integrated processes. Source: ACEA survey result 2014 [10], based on a sample of 67 (out of a total of 74) passenger car paint shops.						

#### 2.2.4.9 New paint shop concepts

In the last 10 to 15 years new paint shop concepts have evolved, which has led to considerable energy savings:

- **integrated process<sup>11</sup>**: elimination of the primer oven by using either:
  - a new base coat type (combining the functions of primer and base coat) applied in two steps;
  - wet-in-wet-in-wet processes ('3-wet');
- **spray-booth air recirculation** in combination with dry separation of paint overspray.

Because of multiple technical constraints, these are generally not possible in existing installations at a reasonable cost, but do offer additional options for the design of new paint shops or in the case of the total refurbishment of existing ones. Currently, 18 % of all EU passenger car paint shops already use one kind of integrated process and many manufacturers consider it the future standard for new greenfield projects. Dry separation of paint overspray is also installed in 18 % of all EU paint shops in at least one of several spray booths.

The total VOC emissions are not significantly affected by these techniques; the main environmental advantages are savings in water (for air humidification) and energy (no primer oven heating, significantly less booth air to condition and move). They also save on floor space (no primer oven, no workplaces between primer (PR) and base coat (BC)).

<sup>11</sup> 'Integrated process' is used in this chapter as an umbrella term for different coating concepts which have one common denominator: all spray coating layers are applied in an uninterrupted sequence of steps without an intermediate bake in a primer oven. Various names and abbreviations are used by paint or equipment suppliers and paint operators for these types of paints or paint shop designs.

### 2.2.4.10 Special products in passenger car paint shops

Paint shop operators are faced with a rising demand for two-tone cars. After the body has been completely coated with one colour, part of the surface is masked and the body is reintroduced to the base coat line to apply the second colour. This results in additional solvent consumption, VOC emissions and energy consumption.

In some installations vans of category N1 are painted together with passenger cars. In contrast to passenger cars, where most of the interior surface of the body-in-white (BIW) is eventually covered by plastic parts, fabric or carpet, vans typically have large visible interior surfaces that need to be coated with the same layers and be of the same quality as exterior surfaces. This leads to higher emissions compared to the coating of passenger cars.

Usually hang-on parts (e.g. bumpers) that are attached to the car body in the final assembly line are painted in separate paint shops. However, in some cases these parts and spare parts for after-sales service are mounted on the car body skids or on separate skids and are coated together with the car bodies in the same paint shop.

### 2.2.5 Painting of vans

Figure 2.11 demonstrates the large variety of the product category 'van'. Classically, these kinds of vehicle present a large combination of bodies/designs which covers mainly category N according to Directive 2007/46/EC<sup>12</sup>, but also derived variants for passenger transport (M1), and depending on the size products that fall under the categories N2 and M2 (minibuses) as well. For the smaller products, their construction principle is generally derived from passenger cars (integral monocoque/unibody), although some manufacturers produce chassis-built vans based on truck design principles.

Generally, the layout and paint application technologies of paint shops for vans are very similar to those of passenger cars, especially as vans are produced and sold in large numbers and are mostly manufactured in high-volume paint shops with a line structure, short cycles and high automation levels.



Figure 2.11: Examples of vehicles defined as vans

The following specific aspects can have an impact on VOC emissions and should be taken into account:

- Coating of large interior surfaces, which leads to higher paint consumption per vehicle and higher specific VOC emissions in  $\text{g/m}^2$  compared to passenger cars.

<sup>12</sup> The Type Approval Directive: Directive 2007/46/EC establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles

- In many cases, robots and electrostatically assisted bells cannot be used in interior coating. Often an additional paint spray booth for the interior coating is required due to the increased cycle time.
- A high proportion of one-layer topcoats, which are available only as solvent-based systems.
- A much larger range of colours are ordered by customers. This includes special fleet colours prescribed by the customers.
- Paint supply systems must be able to provide many colours in any production period.
- Increased cleaning.
- Specific requirements for corrosion protection (wax, layer thickness, etc.) due to different levels of corrosion protection guarantees lead to a greater diversity in coating concepts in van painting installations than in passenger car paint shops.
- Larger installations due to the size of the vehicles.

The coating concepts used are summarised in Table 2.8.

**Table 2.8: Coating concepts for vans**

Layer	EC	PR	BC	CC	TC	Comments
Layer options	WB	WB	WB	SB		
	WB	WB	(WB)	(SB)	WB	BC/CC only for metallic/special colours
	WB	WB	(SB)	(SB)	SB	BC/CC only for metallic/special colours
	WB	SB	(SB)	(SB)	SB	BC/CC only for metallic/special colours
	WB	NA	SB	SB	NA	
	WB	NA	NA	NA	SB	

NB:  
 NA: not applicable  
 EC: e-coat, PR: primer, BC: base coat, CC: clear coat, TC: top coat, WB: water-based, SB: solvent-based  
 Source: Volkswagen AG, Daimler AG, Fiat Chrysler Automobiles N V, Renault, PSA, Iveco, Dürr Systems GmbH, Eisenmann Anlagenbau GmbH & Co KG.

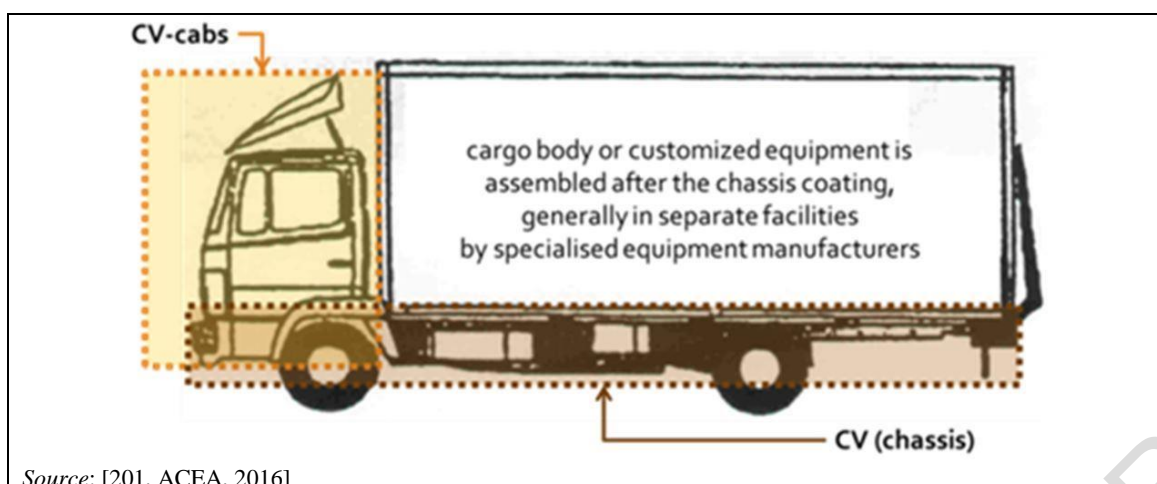
## 2.2.6 Painting of trucks (truck chassis)

Trucks are manufactured in three parts (see Figure 2.12):

- chassis;
- cab;
- cargo compartment / customised equipment.

The truck manufacturer produces and coats the chassis and cabs separately and assembles the cab, engine and transmission onto the chassis, with associated equipment. The production of the truck cargo body (cargo box, tipper, tank, etc.) and trailers and semi-trailers is carried out by specialised manufacturers separate to the truck assembly facility<sup>13</sup>.

<sup>13</sup> Painting of the cargo body is not covered by the IED Annex VII Activity 3 (a) iii (coating of vans and trucks). Coating of these parts or products (where solvent consumption exceeds the IED Annex I thresholds) is included in Chapter 3 'Coating of plastic workpieces and metal surfaces not described in other sections'.



Source: [201, ACEA, 2016]

**Figure 2.12: Typical design of a truck (separate compartments for driver and cargo)**

The truck frame (chassis) is riveted from rails and cross members pre-coated with electrocoat, primer and sometimes also top coat. After the assembly of the drivetrain and other parts onto the frame, the final truck chassis paint operation is to coat the remaining uncoated parts of the chassis, for scratch repair, or for colouring the product according to the customer's requirements. If the coating of the single components or bolt-on parts is done at the same site (which is the case in some large truck factories), these coating operations are included as truck coating operations in the solvent balance boundary of the installation. The coating concepts used are given in Table 2.9.

The following factors affect VOC emissions:

- The number of colours other than black or dark grey is lower than for passenger cars, but is steadily rising, as more and more customers want the truck chassis and cabin in identical or matching colours.
- Due to the complex geometries and the many different chassis types produced by one manufacturer, automation is normally not applied in truck chassis paint shops.

**Table 2.9: Coating concepts for truck chassis coating**

Layer	EC	PR	BC	CC	TC	Comments
<b>Layer concept</b>	*	NA	NA	NA	SB	Final paint is only for colour match and repair
	*	NA	NA	NA	WB	
	*	SB	NA	NA	WB	
	WB	NA	NA	NA	SB	
NB: NA: not applicable * Parts are delivered with EC (sometimes also with TC) and assembled in the truck factory on vehicle chassis. Source: Iveco, Daimler, MAN, Dürr Systems GmbH, Eisenmann Anlagenbau GmbH & Co KG						

For drying, the coated chassis are first transported to a flash-off zone with a maximum temperature of 40 °C and a low air velocity. Afterwards, the paint is dried in a forced air dryer at air temperatures of 85–90 °C. After drying, the chassis are cooled down to ambient temperature and de-masked.



Source: [201, ACEA, 2016] © MAN Truck&Bus

Figure 2.13: Painting of a truck chassis

### 2.2.7 Painting of truck cabins

Driver cabins for trucks are coated separately and are mounted to the truck chassis afterwards. Generally the paint shop design and the paint application technologies are very similar to those of passenger car paint shops. But the following specific aspects must be taken into account:

- Many colours, which are very often available only as solvent-based top coats. Very often special fleet colours are prescribed by the customers and there may be up to 300 colours for a given cabin model.
- Up to 50 % of the cabin surface is covered with plastic parts (mainly polyethylene/ethylene-propylene-diene (PE/EPDM) injection moulded parts), therefore paint systems that work for both surfaces are favoured.
- The diversity in coating concepts in truck cabin painting installations is larger than in passenger car paint shops.

These challenges lead to a high percentage of solvent-based base coats or top coats. With modern solvent-based very-high- or ultra-high-solid paints (SB-VHS/UHS), the same or even lower VOCs to solids ratio as water-based paints can be achieved. TWG: Please confirm. Since the application window for solvent-based systems is much wider than for water-based paints and because the flash-off zones and dryer ovens are shorter and consume less energy, these paint shops have a better environmental performance compared to those with water-based paints especially in regions with long periods of high temperatures and humidity.

There are many different coating concepts which are embedded in the overall assembly and production logistics strategy of the respective manufacturer (see Table 2.10). Paint systems that have curing temperatures of 80 °C to 90 °C and are equally applicable for metal and plastic surfaces (so plastic part painting can be integrated into the cabin paint shop) are already frequently used for cabin painting in non-EU installations and will certainly be introduced in more EU paint shops in the future.

Table 2.10: Coating concepts for truck cabins

Layer	EC	PR	BC	CC	TC	Comments
Layer options	NA	PO	WB	SB 2K	(WB)	TC for non-metallics at the same line
	NA	NA	SB	SB		Cabin + plastic parts, 80 °C process
	WB	WB	NA	NA	WB	
	WB	WB	WB	SB	(WB)	TC for non-metallics at the same line
	WB	WB	WB	SB		
	WB	WB	NA	NA-	SB	
	WB	SB	WB	SB	(WB)	TC for non- metallics at the same line
	WB	WB	SB	SB	NA	
	WB	NA	NA	NA	SB	
	WB	SB	SB	SB	NA	
	WB	NA	SB	SB	NA	

MB: NA: Not applicable  
Source: [201, ACEA, 2016]

Most paint shops have automatic application systems (robots) and paint supply systems that are adapted to supply small quantities (consumption 100 kg/d to 200 kg/d) and permit the rapid change of many different colours, in some cases more than 300 for a given cabin model.



Figure 2.14: Truck cabin painting

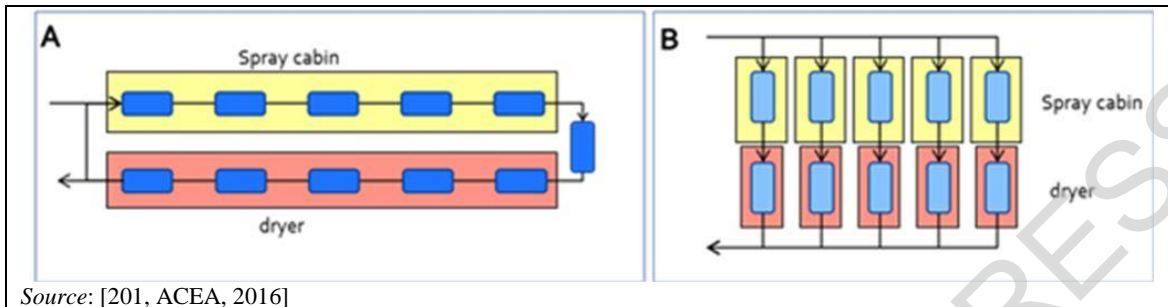
### 2.2.8 Coating of buses

In principle, the descriptions of processes and techniques in Section 2.2.4 are valid for bus coating as well. Major differences are outlined here.

Compared to passenger cars, the production volumes of buses are much smaller. Consequently, paint shops are generally designed for lower outputs (< 20 units per day). Two design and operating principles can be found:

- instead of separate spray booths for each coat layer, one multifunctional paint line is used and the bodies are transferred repeatedly through the same line until all necessary coat layers are applied;
- painting is done in paint boxes instead of sequential paint lines (see Figure 8, a general description of this concept was recently published.).

In some cases, the coating process of a bus is split over two or three different production sites, with each site operating a bus paint shop which is responsible for the application of one or more paint layers. This is generally not found in the mass production of passenger cars.



Source: [201, ACEA, 2016]

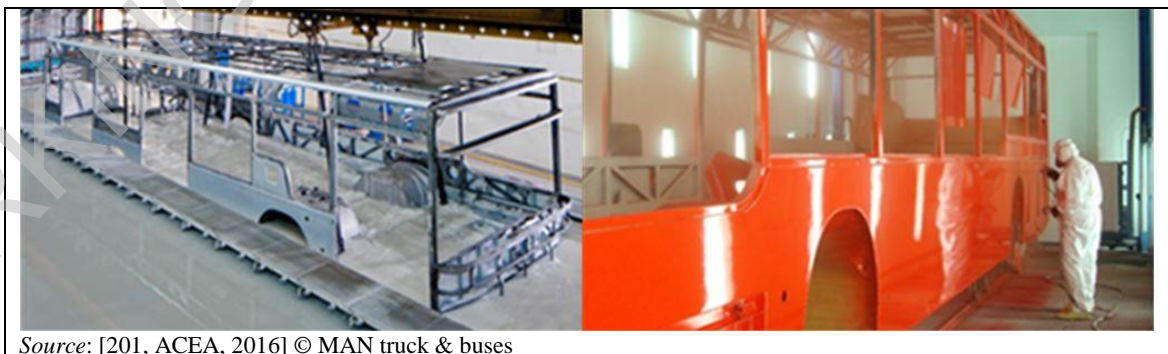
**Figure 2.15: Different design concepts for large (A: sequential paint line) and medium or small (B: paint boxes) production capacities**

An important feature in bus coating is the customer demand for brand-specific colours, so paint shops have to handle more than 400 different tones and very often multi-coloured buses and coaches are ordered.

Not all bus bodies are electrocoated. The interior surface of city buses is generally coated whereas coaches, especially in the luxury sector, are almost completely covered with interior plastic parts and need no top coat. Therefore the painted surfaces and the VOC emission in  $\text{g}/\text{m}^2$  are very different in both groups. For touring buses, different floor coverings are used; these materials are fixed with double-sided adhesive foils or bonded via dispersion adhesives, which are in some cases solvent-based. Underbody protection is very often applied as an undercarriage coat after the final assembly of the bus

The material is applied using HVLP, conventional airmix or airless spray guns. Overspray is separated with wet scrubbers or dry filters.

For drying, the coated chassis are first transported to a flash-off zone with a maximum temperature of  $40\text{ }^\circ\text{C}$  and low air velocity. Afterwards, the paint is dried in a forced air drier at air temperatures of  $85\text{--}90\text{ }^\circ\text{C}$ . After drying, the chassis are cooled down to ambient temperature.



Source: [201, ACEA, 2016] © MAN truck & buses

**Figure 2.16: Coating operations for buses: e-coat (left) and top coat (right)**

Table 2.11: Coating concepts in bus coating

Layer	EC	PR	BC	CC	TC	UC	Comments
Layer options	WB	NA	NA	NA	NA	NA	After E-coat transfer to other paint shop
	WB	*	*	*	SB	NA	Finish after assembly of bus
	*	SB	WB	SB	(SB)	NA	Top coat only for non-metallics
	WB	WB	SB	SB	NA	NA	
	-	SB	WB	SB	(SB)	SB	Top coat only for non-metallics
	SB	WB	NA	NA	SB	NA	Epoxy primer as substitute for electrocoating
	SB	SB	NA	NA	SB	NA	
	WB	SB	SB	SB	NA	SB	
	*	SB	SB	SB	(SB)	SB	Top coat only for non-metallics
* Done in a separate paint shop. NB: UC = Undercarriage coat for stone chip protection. NA: Not applicable Source: Iveco S.p.A., MAN Truck & buses, Daimler AG, Scania AB							

Waste gas treatment is applied to reduce the VOC emission of dryer oven waste gases (EC oven, TC oven) at large installations. For smaller installations, no abatement techniques are used.



### 2.3 Current consumption and emission levels in the coating of vehicles

[155, TWG, 2016] [142, ACEA, 2016] [147, TFTEI, 2016] [145, ACEA, 2016] [146, ACEA, 2017]

The vehicle manufacturers' data for VOC mass emission figures from individual paintshops are generally comparable across Europe because they are standardised in line with the SED. However, data from sources such as materials/equipment suppliers or from outside the EU may not be comparable due to technical differences (e.g. colour change, cleaning solvents). Other consumptions and emissions are not readily comparable due to the diverging interpretation of the IPPC 'installation' among Member States. Nevertheless, the integrated approach in IPPC is very important and the impacts of each technique on other emissions and emissions to other media should also be considered in detail.

A significant number of installations for the coating of passenger cars (PC) participated in the data collection (29). The number of installations for the coating of vans (VAN), trucks (TC) and truck cabins (CAB) was significantly lower, seven in total, and there was only one installation for the coating of buses [155, TWG, 2016]. Consumption and emission data were completed using other sources [142, ACEA, 2016], [147, TFTEI, 2016].

Nominal values for layer thickness, material solids and VOC contents, material consumption and emission contribution are presented in the following table.

Table 2.12: Solvent and solid contents of coating materials

	Dry-film thickness	Solids content <sup>(1)</sup>	VOC content <sup>(2)</sup> ready for use	Material consumption <sup>(3)</sup>	Emission contribution <sup>(3)</sup>
	in µm	in % m	in % m	in kg/body	in g/m <sup>2</sup>
Cathodic dip paint, replenishment material		38 to 42	2 to 4	6,0 to 7,0	
Cathodic dip paint, dip tank	18 to 22 exterior > 10 interior	16 to 20	1 to 2		0,6 to 1,0
Solvent-based primer	20 to 40	50 to 65	35 to 50	1,4 to 2,8	4,0 to 8,0
Water-based primer	20 to 40	45 to 55	5 to 12	1,2 to 2,4	0,5 to 1,5
Powder-based primer	60 to 90	100	0	2,0 to 2,5	0
Solvent-based base coat <sup>(4)</sup>	10 to 15 (25)	18 to 22 (40)	78 to 82 (60)	2,5 to 3,5	20,0 to 30,0
Solvent-based base coat <sup>(5)</sup> (high solid)	12 to 20 (25)	35 to 45 (50)	55 to 65 (50)	1,5 to 2,2	10,0 to 15,0
Water-based base coat <sup>(6)</sup>	10 to 15 (25)	16 to 22 (40)	12 to 17	2,5 to 3,5	3,0 to 6,5
Integrated process (entire coat without clear coat)	15 to 30 (35)	16 to 30 (40)	10 to 18	3,0 to 5,0	3,0 to 7,5
Solvent-based clear coat	30 to 55	47 to 54	46 to 53	2,1 to 3,0	7,0 to 12,0
Clear coat (high solid, 1K)	30 to 55	55 to 60	40 to 45	1,8 to 2,4	6,0 to 10,0
Clear coat (high solid, 2K)	30 to 55	55 to 65	35 to 45	1,6 to 2,4	5,0 to 9,0
Water-based clear coat (2K)	30 to 45	45 to 50	8 to 15	2,2 to 2,8	1,5 to 4,0
Powder slurry	30 to 40	37 to 40	< 1	2,3 to 2,8	0,5 to 1,0
Powder-based clear coat	60 to 80	100	0	1,4 to 1,8	0
Solvent-based top coat (1K)	35 to 50	45 to 60	40 to 55	2,8 to 4,0	9,0 to 18,0
Solvent-based top coat (2K)	35 to 50	55 to 70	30 to 45	2,4 to 3,5	7,0 to 14,0
Water-based top coat (1K)	35 to 50	45 to 55	5 to 13	3,1 to 4,5	1,5 to 4,5
Water-based top coat (2K)	35 to 50	45 to 50	12 to 18	3,4 to 5,0	3,5 to 7,0
Underscaling	200 to 1000	95 to 98	2 to 5	1 to 5	0,2 to 3,0
Weld sealing	Ø: (2 to 10) mm	95 to 98	2 to 5	3 to 9	0,7 to 4,0
Sprayable damping material	1500 to 5000	70 to 99	0 to 3	2 to 8	0 to 2
Cavity preservation material, VOC-free		various	0	1 to 2	0
Cavity preservation material, with VOCs		70 to 85	15 to 30	1 to 2	2,0 to 5,0
Rinsing agent for solvent-based primer		0	100	per sprayer: colour change: 15 m <sup>2</sup> paint 200 m <sup>2</sup> rinsing agent <sup>(7)</sup> short rinse: BC: after (1 to 5) bodies CC: after (5 to 10) bodies (20 to 30) m <sup>2</sup> solvent	depending on the process and mode of operation of the painting plant
Rinsing agent for water-based primer		0	10 to 15		
Rinsing agent for solvent-based BC		0	100		
Rinsing agent for water-based BC		0	10 to 15		
Surfactant-based rinsing agent		0	0		
Rinsing agent for CC		0	100		
Plant cleaning, diluent, mixing chamber, laboratory		0	0 to 100	< 1	

General reference values for medium-sized passenger cars. Other conditions may apply from case to case for quality reasons, depending on the vehicle type. Particularly, different requirements are usually valid for exterior and interior painting.

<sup>(1)</sup> when ready for use

<sup>(2)</sup> Sprayed paint quantity per body; the overall usage may be higher due to colour-change losses and second runs.

acc. to 31. BImSchV (Federal Immission Control Ordinance), guide values for usual application conditions and plant configurations (no treatment of booth exhaust)

<sup>(3)</sup> Values in parentheses apply for low-opacity colour shades, such as white or beige (German taxi colour).

\* In a so-called soft purge procedure, a new primer colour is fed while still painting the rear of the preceding vehicle. This eliminates the need of rinsing when changing colours.

Source: [169, VDI, 2013]

## 2.3.1 Consumption

### 2.3.1.1 Energy consumption

Energy consumption in the painting process represents about 30 % of the total energy consumption in car manufacturing and is probably the most environmentally significant in vehicle production after considering solvent use and emissions. The main share of consumed energy is supplied as natural gas and used for heating of dryers and thermal abatement of solvent-containing off-gases.

Table 2.13 provides the analysis of energy consumption per process step.

**Table 2.13: Typical energy consumption of car paint shops**

Typical energy consumption of car paint shops	
<b>Production capacity</b>	200000 cars/year
<b>Coating system</b>	Water-based filler and base coat, solvent-based 2K clear coat
<b>Energy consumption of paint shop</b>	<b>Units range</b>
<b>Total energy consumption (plant)</b>	380000 – 580000 MWh
Energy consumption of paint shop (60 % gas)	160000 – 240000 MWh
Paint shop as % of total plant energy	38 – 52 %
<b>Energy consumption of paint processes</b>	
	<b>Range</b>
Pretreatment	7 – 11 %
E-coating	10 – 15 %
Seam sealing/underbody protection	12 – 18 %
Filler	12 – 18 %
Base coat	15 – 22 %
Clear coat	22 – 33 %
Cavity sealing	2 – 2 %
Total	80 – 120 %
Sources: Ökobilanz Lackierprozess (2003) (Krinke), Pers. Mittl. Hr. Engelmann, Oct 2005, ACEA 2005 [78, TWG, 2005]	

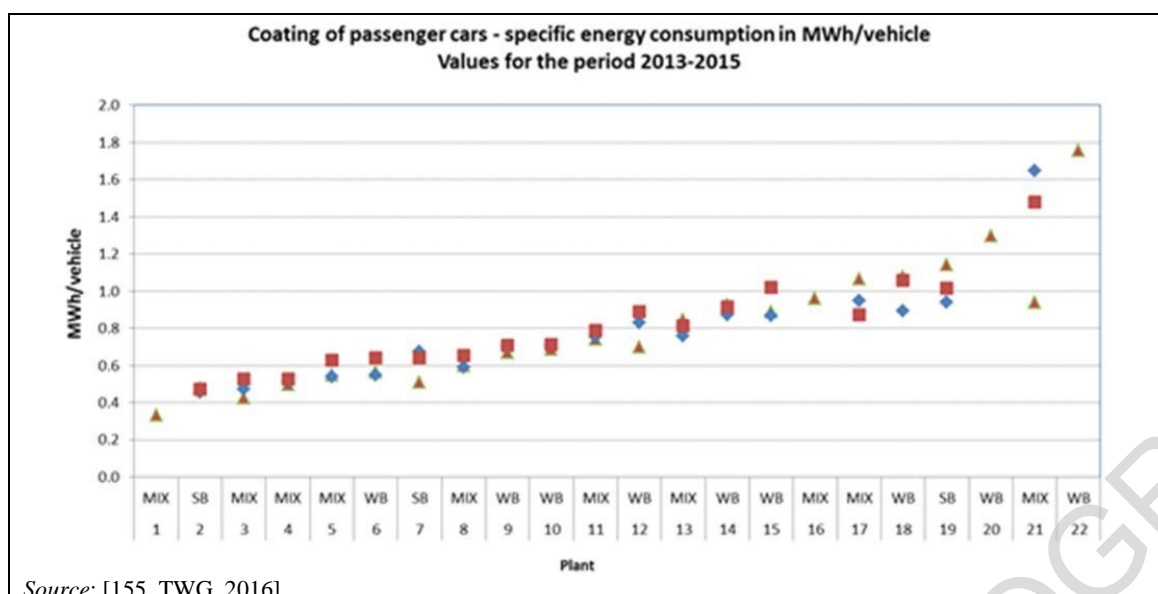
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It is difficult to quantify the impact of climatic conditions on the overall energy consumption of the paint shop. This is due mainly to lack of energy metering systems that cover specific aspects of the paint shop and all the potential forms of input energy (electricity, gas). Sporadic reported data indicate a range between 1 % and 16 % of the total energy consumption being related to local climatic conditions (e.g. for heating/cooling or dehumidifying the process air).

Energy consumption could be measured by using utility meters connected to a main data acquisition system. When dedicated metering is not available, the paint-shop-related energy consumption can be calculated by using broader energy consumption data and suitable correction factors (see also [109, COM, 2009]).

#### Passenger car coating

Figure 2.17 shows the reported data for the specific energy consumption of passenger car plants (PC paint shops), expressed in MWh/vehicle.



**Figure 2.17: Specific energy consumption (MWh/vehicle) in passenger car plants (PC paint shops)**

The following table summarises the reported data on specific energy consumption for the passenger car coating plants.

**Table 2.14: Specific energy consumption data for passenger car plants (PC paint shops)**

Product type	# of plants	Reported data <sup>(1)</sup>			Industry report <sup>(2)</sup>			
		Average 2013–2015 (MWh /unit)	50 % middle range (MWh /unit)	Max./Min. (MWh /unit)	# of plants	2012 Data (MWh /unit)	50 % middle range (MWh /unit)	Max./Min. (MWh /unit)
PC	22	0.83	0.59–0.96	1.76/0.33	68	0.87	0.64–1.04	3.53/0.32

<sup>(1)</sup> Source: [155, TWG 2016]  
<sup>(2)</sup> Source: [142, ACEA, 2016]

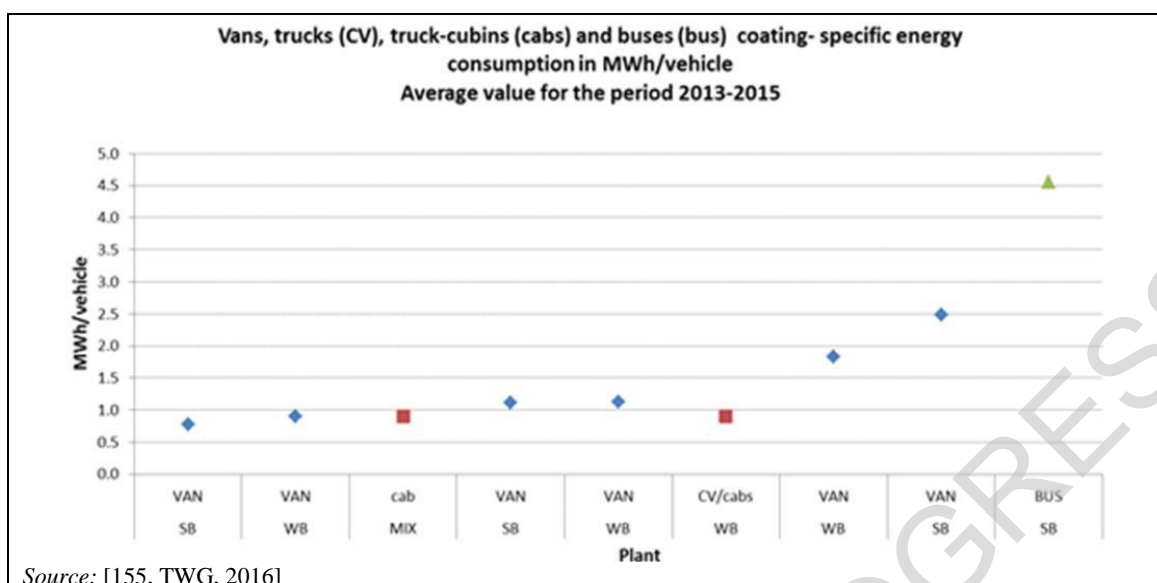
For passenger car paint shops, most of the reported specific energy consumption values are below 1 MWh/vehicle, with an average value of 0.825 MWh/vehicle.

An industry report summarising data from 68 paint shops shows an average specific energy consumption of 0.87 MWh/vehicle [142, ACEA 2016].

Significant yearly deviations in the specific energy consumption are not observed except in one plant reporting a significant increase (more than tripling) in the throughput figure which is associated with the increase in the utilisation of the installed paint shop capacity and the more efficient use – in energy consumption terms – of the available infrastructure.

### Coating of vans, trucks, truck cabins and buses

Figure 2.18 shows the reported data for the specific energy consumption in van, truck, truck cabin and bus plants (van, CV, cab and bus paint shops), expressed in MWh/vehicle.



**Figure 2.18: Specific energy consumption (MWh/vehicle) in van, truck, truck cabin and bus plants**

The following table summarises the reported data on specific energy consumption per product type.

**Table 2.15: Specific energy consumption data for van, truck, truck cabin and bus coating plants**

Product type	Reported data <sup>(1)</sup>				Industry report <sup>(2)</sup>			
	# of plants	Average 2013–2015 (MWh/unit)	50 % middle range (MWh/unit)	Max./Min. (MWh/unit)	# of plants	2012 Data (MWh/unit)	50 % middle range (MWh/unit)	Max./Min. (MWh/unit)
Van	6	1.37	0.95–1.65	1.76/0.33	9	1.70	1.12–3.00	3.49/0.85
Cab/ CV	2	1.08	NI	1.21/0.96	Cab:8	1.33	0.88–1.88	6.23/0.55
					CV: 4	0.31	NI	0.44/0.27
Bus	1	4.55	NI	NI	8	14.9	3.0–21.8	37.1/1.7

<sup>(1)</sup> Source: [155, TWG 2016]  
<sup>(2)</sup> Source: [142, ACEA, 2016]

Among the reported energy-saving techniques, the most commonly applied are:

- thermal insulation of tanks and vats with heated liquids;
- heat recovery from waste gas abatement;
- adjustment of the flow according to need; reduced air ventilation at idle operation or maintenance;
- air extraction with energy recovery from the dryer ovens;
- air extraction with energy recovery from the cooling zone;
- central waste gas treatment with variable frequency drives;
- pressurised air: efficiency/pressure level;
- spray booth air recirculation.

### 2.3.1.2 Water consumption

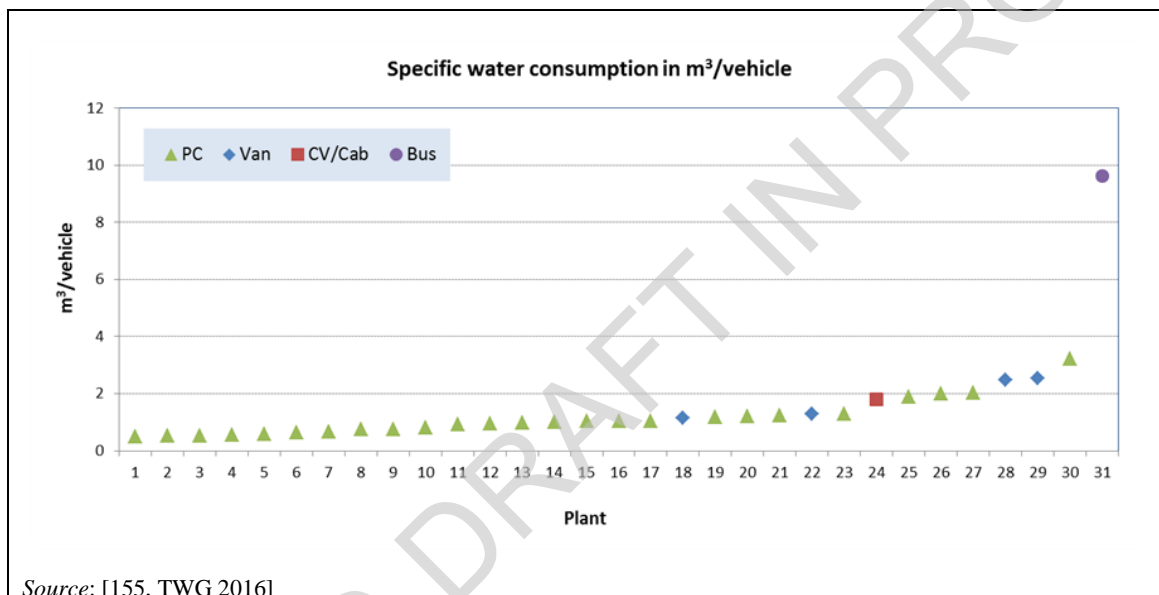
Water consumption in vehicle paint shops is mainly related to the:

- supply of rinsing water in cleaning and pretreatment processes;
- replenishing of degreasing and pretreatment tanks and wet scrubber systems;
- evaporation loss from wet scrubber systems.

Bath maintenance with the objective to reduce water consumption and to reclaim treatment chemicals is an important part of the paint shop management. Rinsing tanks are generally operated as cascading vats. [142, ACEA, 2016].

Figure 2.19 and Table 2.16 shows data on the specific water consumption (expressed in m<sup>3</sup>/vehicle) reported by various installations. Most of the reported specific water consumption values are below 1.3 m<sup>3</sup>/vehicle.

An industry report indicates a specific water consumption between 0.9 m<sup>3</sup>/vehicle and 1.8 m<sup>3</sup>/vehicle, with consumption values below 0.4 m<sup>3</sup>/vehicle reported from paint shops with a special body design (small vehicles) or from installations with dry particle separation [142, ACEA, 2016].



Source: [155, TWG 2016]

Figure 2.19: Specific water consumption (m<sup>3</sup>/vehicle) in automotive paint shops

The following table summarises the reported data on specific water consumption for automotive paint shops per vehicle type.

Table 2.16: Specific water consumption data for automotive paint shops

Product type	Reported data <sup>(1)</sup>				Industry report <sup>(2)</sup>			
	# of plants	2015 Data (m <sup>3</sup> /unit)	50 % middle range (m <sup>3</sup> /unit)	Max./Min. (m <sup>3</sup> /unit)	# of plants	2012 Data (m <sup>3</sup> /unit)	50 % middle range (m <sup>3</sup> /unit)	Max./Min. (m <sup>3</sup> /unit)
PC	25	1.09	0.67–1.20	3.23/0.48	47	1.18	0.90–1.82	
Van	4	1.87		2.54/1.15	3	2.05		3.26/0.96
Cab/CV	1	1.81			Cab:7	2.63	0.66–2.78	7.61/0.15
					CV: 5	4.21	0.15–0.56	6.98/0.10
Bus	1	9.63			5	14.6	4.1–29.9	54.6/10.6

<sup>(1)</sup> Source: [155, TWG 2016]  
<sup>(2)</sup> Source: [142, ACEA, 2016]

The main reported techniques for minimising water consumption are:

- reuse of water;
- control of water usage;
- reverse cascade rinsing;
- bath desludging;
- ion exchange;
- membrane filtration;
- oil skimmer;
- particle filter;
- magnet separator;
- decanter centrifuging for paint shop overspray waste waters;
- neutralisation.

### Mass balances

No information submitted.

### Consumptions

### Materials

shows consumption of paint in grams per painted m<sup>2</sup> of the car's body surface area, where the VOC emission and the surface area are as measured according to the techniques described in detail in Annex 21.6. The consumption depends on the different paint systems and application systems, etc. It should be remembered that this is for information only, and cannot be a 'pick list' to select a paint system on the basis of consumption efficiency only. The paint process in each installation is highly complex and fully integrated comprising many integrated steps: each step influences others and different figures apply according to application techniques. Decisions about best options therefore cannot be taken on the basis of selecting each step individually.

Painting material <sup>(4)</sup>	Specific material consumption (g paint/m <sup>2</sup> ) <sup>(4)(6)</sup> except <sup>(3)</sup>
Electrocoating: water based, 5 wt % organic solvents, solid content of 14–18 %	70–80
Primer: solvent based, 45 wt % organic solvents, electrostatically assisted spray application	10–15
Primer: water based, 8 wt % organic solvents, solid content of 50–55 %, electrostatically assisted spray application	10–20
1 coat topcoat: solvent based, 45 wt % organic solvents, electrostatically assisted spray application	35–60
Base coat: solvent based, 75 wt % organic solvents, <sup>(5)</sup> electrostatically assisted spray application (60 %) and compressed air spray application (40 %)	45–55 <sup>(2)</sup>
Base coat: water based, 13 wt % organic solvents, solid content 17–35 %, electrostatically spray application (60 %) and compressed air spray application (40 %). <sup>(5)</sup>	45–60 <sup>(2)</sup>
Clear coat: solvent based, 45 wt % organic solvents, electrostatically assisted spray application	20–30
Clear coat: water based, 14 wt % organic solvents, solids content of 42–49 %, electrostatically assisted spray application	35–45
Clear coat: powder slurry, about 1 wt % organic solvents, solids content of 38 % electrostatically assisted spray application	42–46
Clear coat: powder based, solvent free, electrostatically assisted spray	100–110

application	
Underbody protection and seam sealing	6—12 kg/car body <sup>(3)</sup>
Transport and delivery protection	6
<sup>(1)</sup> Electrocoated area as defined in the SED. This unit is valid for all cited paint systems except the underbody protection and the seam sealing; for the latter no area-related unit can be given <sup>(2)</sup> For base coats with a solids content of 20—25 wt % during processing <sup>(3)</sup> kg/car body not g/m <sup>2</sup> <sup>(4)</sup> Electrostatic applications expect to have higher application rates and pneumatic lower, <sup>(5)</sup> The percentages relate to proportion of the film thickness achieved by the base coat film applied: 60 % relates to using electrostatic high rotation bells (e.g. 9 μ) versus 40 % by pneumatic application (e.g. 6 μ). Repairs by pneumatic spraying show visible differences of metallic finishes applied by electrostatic coating, so serial coating using pneumatic sprays makes repairs during lifetime easier. <sup>(6)</sup> Measured according to the techniques described in detail in Annex 21.6.	

**Table—Specific paint consumption of several paint systems**  
 [13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

### Water

The main water using areas are:

- pretreatment (degreasing)
- conversion coatings (phosphating and passivation)
- electrocoating
- cleaning of the spray booth exhaust air.

The primary use of water is in rinsing off materials prior to the next process: a small amount is used for topping up from evaporation, and making new solutions. Water management and saving techniques for these are described in detail in the STM BREF [59, EIPPCB, 2006]. These include multistage rinsing, techniques to minimise water use, recovery of water and raw materials, and are equally applicable to electrocoating. Consumption ranges associated with BAT given in the STM BREF are: 3—20 l/m<sup>2</sup>/rinse stage.

The painting department of a major German company has reduced water consumption by about 70 % down to 3 litres/m<sup>2</sup> due to the use of all possible water saving techniques, such as closed loops and multiple stage cascade systems in the rinsing zones of the pretreatment and the electrocoating primer installations. This included installing a new phosphating plant. Assuming this included three rinse stages (one each for degreasing, phosphating, electrocoating), then the consumption range associated with BAT given in the STM BREF would be 9—60 l/m<sup>2</sup>.

Spray booths have a curtain of water catching overspray. These are normally a closed loop of the water circulating in the booth, with paint coagulation. The waste is a sludge like coagulate and little waste water is generated. The booths require emptying occasionally for cleaning, and need some water to replace evaporative losses.

Water can be used for cooling. This is discussed in the CV BREF [126, EIPPCB].

### Energy

The painting process is one of the most energy intensive steps and is probably the most environmentally significant in vehicle production after considering solvent use and emissions. gives typical values for car paintshops, showing the energy consumption is 38—52 % of the energy consumption for an entire assembly plant (excluding other production activities sometimes located in the same plant, such as foundries, engine block manufacture and production of other component production). Details of the energy consumption for a specific sequence of processes and of individual process steps depend on the type of processes and the individual production line capacities. Because of this, data are often not comparable, even



between different production lines within the same site. Detailed data often do not exist or are not published.

## 2.3.2 Emissions

### 2.3.2.1 VOC emissions

In the production of cars, vehicle coating, VOCs represent the most significant emission source. The activity emits NMVOC originating from the spray booths, the drying ovens and the cleaning of application equipment. NMVOC emissions from this sector may vary significantly from country to country. At EU 25 level for 2000 (according to the RAINS model), NMVOC emissions were 74.2 kt representing 0.7% of total NMVOC emissions. Total activity was 18367150 vehicles coated, and the average emission factor was about 4 kg NMVOC/vehicle. This shows that emissions from this sector are already partly treated\* in the EU 25 (the untreated\* emission factor is country specific but can be as high as 10 kg/vehicle). This figure equates to an EU 25 average of about 40–67 g VOC/m<sup>2</sup>, compared with the untreated situation of about 100–167 g VOC/m<sup>2</sup> (both ranges depend on the model size). The industry has invested significantly in solvent reduction activities and before introducing reduction measures (e.g. in the 1970s), typical emission levels were between 200 and 300 g/m<sup>2</sup> (measured according to the SED) [67, ACEA, 2005]. (\*Treated/untreated in this context means not only waste gas treatments but also all other measures to reduce VOC emissions). The emissions and surface areas are calculated according to Annex 21.6.

The SED set a VOC mass emission limit for vehicle painting installations of 60 g/m<sup>2</sup> for existing installations and 45 g/m<sup>2</sup> for new installations. The deadline for achieving the mass emission limit for existing plants is 31 October 2007. In early 2005, 27 plants in Europe operated above the 60 g/m<sup>2</sup> limit and have upgrade programmes in place to achieve the limit within the deadline [67, ACEA, 2005].

Most Member States apply the SED limits, but there are lower emission limits applied in some Member States. Germany, for instance, has a long tradition of implementing VOC legislation, which has required industry to reduce emissions over 20 years from 60 to 35 g/m<sup>2</sup> for solid paint. Similar legislation applies in Austria and the Czech Republic [78, TWG, 2005].

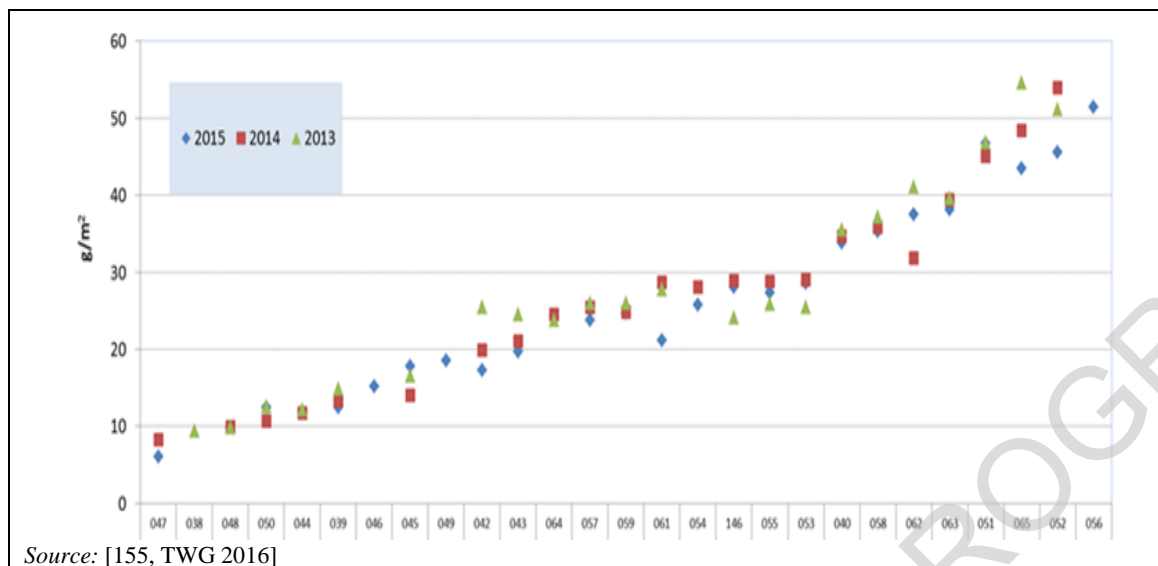
Usually, application and drying of primer and topcoat/clear coat contribute to approximately 80 % of the VOC emissions originating from the painting sector of car production. The topcoat refinishing (rectification) and cleaning procedures as well as additional sources (e.g. coating of small parts, application of underbody protection) are responsible for the remaining 20 %. Approximately 70–90 % of the total VOC emissions generated during the application and drying procedure originate from the painting booth; the remaining 10–30 % from the dryer. The indicated percentage rates generally depend on the solvent types used, the painting systems and the application efficiency factor of the technique. Waste air from the dryer loaded with VOCs is supplied to a thermal waste gas cleaning system.

VOC emissions in the vehicle coating sector are expressed as specific emissions in g VOC/m<sup>2</sup> of coated surface.

#### Coating of passenger cars

Figure 2.20 presents the reported total emissions from 27 paint shops in Europe dedicated to the coating of passenger cars (PC) and light commercial vehicles (LCV). According to the type of coating used for the various coating layers (primer, base coat, clear coat), paint shops are classified as SB (solvent-based: use of solvent-based coat for all layers), SB-MIX (use of water-based coat for either the primer or base coat, and solvent-based for the other coats) and WB (water based: use of water-based coating for all layers except clear coat). Another option, the integrated system, exists, but was not identified in reports from the 27 paint shops. According to

ACEA, the VOC emissions from integrated systems are similar to those of other well-performing systems and these systems are implemented for other reasons (see Section 2.2 and [142, ACEA, 2016]).



**Figure 2.20: Reported values of total VOC emissions ( $\text{g}/\text{m}^2$ ) for passenger car paint shops**

An industry report analysing data from 74 passenger car paint shops shows an average value of  $25.1 \text{ g}/\text{m}^2$  and a 50 % mid range between  $16 \text{ g}/\text{m}^2$  and  $33 \text{ g}/\text{m}^2$  [142, ACEA, 2016].

The TFTEI<sup>14</sup> report analysing data from 60 reference paint shops in Europe provide the emission values that are presented in Table 2.17 in relation to the paint shop type [147, TFTEI, 2016].

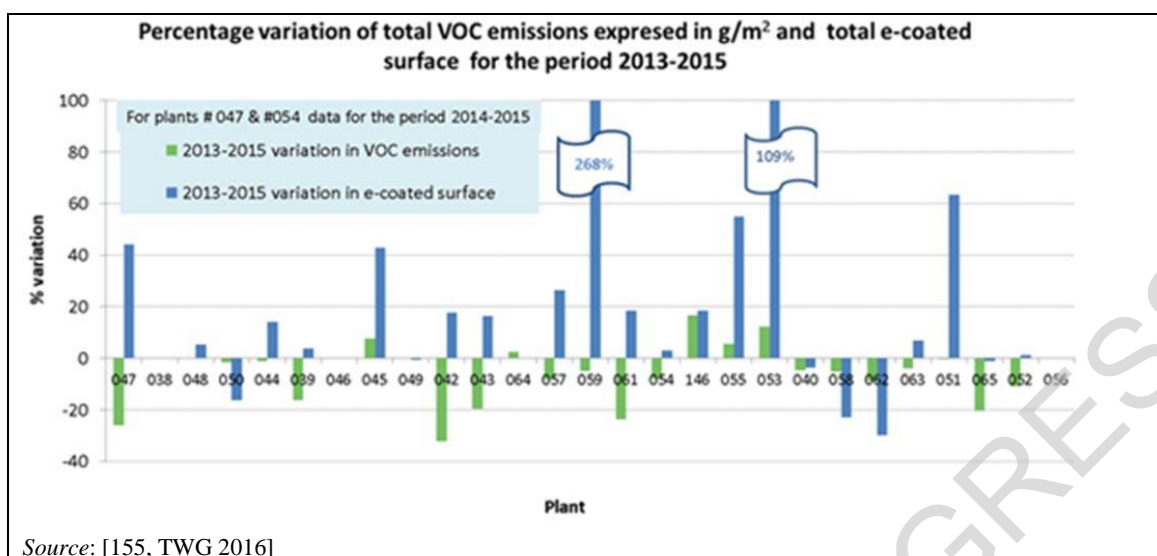
**Table 2.17: Specific VOC emissions for various paint shop types**

Paint shop type VOC EMISSION ( $\text{g}/\text{m}^2$ )	SB	SB-MIX	WB	Integrated system
Average	37.8	28.7	18.6	20.5
Min. – Max.	16.8–50.3	12.5–48.2	6.0–30.5	8.9–32.1

Source: [147, TFTEI 2016]

During the reference period (2013–2015), for most of the installations that submitted data, a decrease in total VOC emission values is observed. This, in most cases, is combined with an increase in the utilisation of the installed plant (paint shop) capacity (see Figure 2.21 below).

<sup>14</sup> TFTEI: Task Force on Technico-Economic Issues of the UNECE Convention on Long Range Transboundary Air Pollution (LRTAP)



**Figure 2.21: Percentage variation of reported total VOC emissions (g/m<sup>2</sup>) and total e-coated surface) for the period 2013–2015**

For example, data from two installations show:

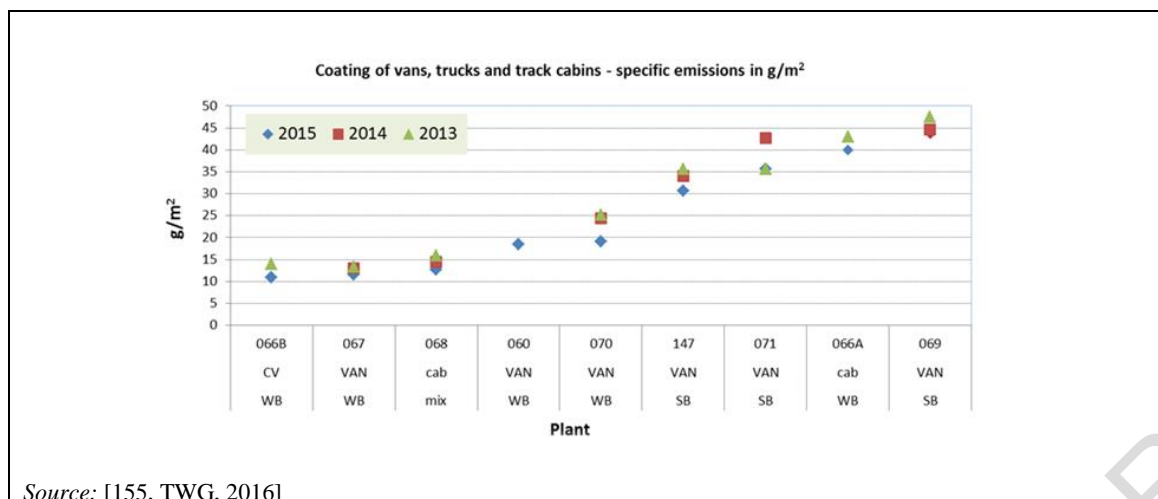
- a reduction of almost 24 % in total VOC emissions which can be correlated with the reduction of 10 % in total VOC emitted load and the increase of 18 % in coated surface for the period 2013–2015 (*Source: 155, TWG 2016, #061*);
- a reduction of 26 % in specific VOC emissions combined with an increase of about 6 % in total VOC emitted load and an increase of 40 % in coated surface between the years 2014 and 2015 (*Source: 155, TWG, 2016, #047*).

Apart from major changes in the paint shop design and technology which are mainly associated with the installation's investment cycle, a number of other techniques can contribute to significant emission reduction. As an example, information from one installation shows that the implementation of the following –mainly managerial and not major investment– techniques had as a result the reduction of specific emissions by 34 % over a nine-year period (from 53.76 g/m<sup>2</sup> in 2007 to 35.41 g/m<sup>2</sup> in 2016) (*Source: 155, TWG, 2016, #058*):

- implementation of low-pressure manual paint sprayers;
- decrease in the number of paint colours;
- only one coat for three types of coat;
- increase in the number of cars in series of cars of the same colour;
- work on the pulverisation efficiency by optimising the application distance (base and clear coats);
- use of low-solvent products to clean the spray painting robots which are protected by a cover;
- improving the percentage of directly well-painted cars (increased 'right first time' rate) and implementation of the localised repairing technique.

### Coating of vans, trucks, truck cabins and buses

Reported data from nine paint shops dedicated to van, truck and truck cabin coating are presented in Figure 2.22.



Source: [155, TWG, 2016]

**Figure 2.22: Specific VOC emissions ( $\text{g}/\text{m}^2$ ) for paint shops for the coating of vans, trucks and truck cabins**

There are data reported for only two installations for truck cabin coating, both of them below  $45 \text{ g}/\text{m}^2$  ( $14.32 \text{ g}/\text{m}^2$  and  $41.5 \text{ g}/\text{m}^2$  as averages for the period 2013–2015).

An industry report with an analysis of data from 11 truck cabin paint shops shows an average value of  $21.2 \text{ g}/\text{m}^2$  with the 50 % mid range varying from  $14.1 \text{ g}/\text{m}^2$  to  $51.3 \text{ g}/\text{m}^2$  [142, ACEA, 2016].

The reported data from seven paint shops for the coating of new vans and trucks chassis show an average value of  $26.2 \text{ g}/\text{m}^2$  with values ranging from  $14.3 \text{ g}/\text{m}^2$  to  $45.2 \text{ g}/\text{m}^2$  (all values are averages over the period 2013–2015).

An industry report analysed data from 10 paint shops for van coating and 6 paint shops for truck chassis and derived average values of  $33 \text{ g}/\text{m}^2$  and  $50 \text{ g}/\text{m}^2$  respectively for the two product types.

The basic statistical figures from the reported data are presented in Table 2.18.

**Table 2.18: Specific VOC emission data for automotive paint shops**

Product type	Reported data <sup>(1)</sup>				Industry report <sup>(2)</sup>			
	# of plants	Average over the period 2013–2015 ( $\text{g}/\text{m}^2$ )	50 % middle range ( $\text{g}/\text{m}^2$ )	Max./Min.	# of plants	2012 Data ( $\text{g}/\text{m}^2$ )	50 % middle range ( $\text{g}/\text{m}^2$ )	Max./Min.
PC	27	26.2	15.6–35.4	51.4/7.1	74	25.1	15.9–32.9	55.3/4.7
Van/CV	7	26.2	15.5–35.8	45.2/12.5	Van:10	33	24–47	61/16
					CV:6	50.5	22.2–56.9	68.1/17
Cab	2	27.9	NA	41.5/14.3	11	21.2	14.1–51.3	70.6/8.3
Bus	1	95.3	NA	NA	10	64.6	36.9–118	183/4.4

<sup>(1)</sup> Source: [155, TWG 2016]

<sup>(2)</sup> Source: [142, ACEA, 2016]

### 2.3.2.2 Dust emissions to air

Besides VOC emissions, dust emissions resulting from paint overspray are also considered a key environmental issue for the sector. All paint shops are equipped with venturi scrubbers or dry scrubbers to reduce dust emissions arising from paint overspray.

Figure 2.23 shows the reported dust emission values from vehicle paint shops applying wet or dry dust abatement techniques or in cases where the abatement technique was not reported. The reported concentration values are generally low.

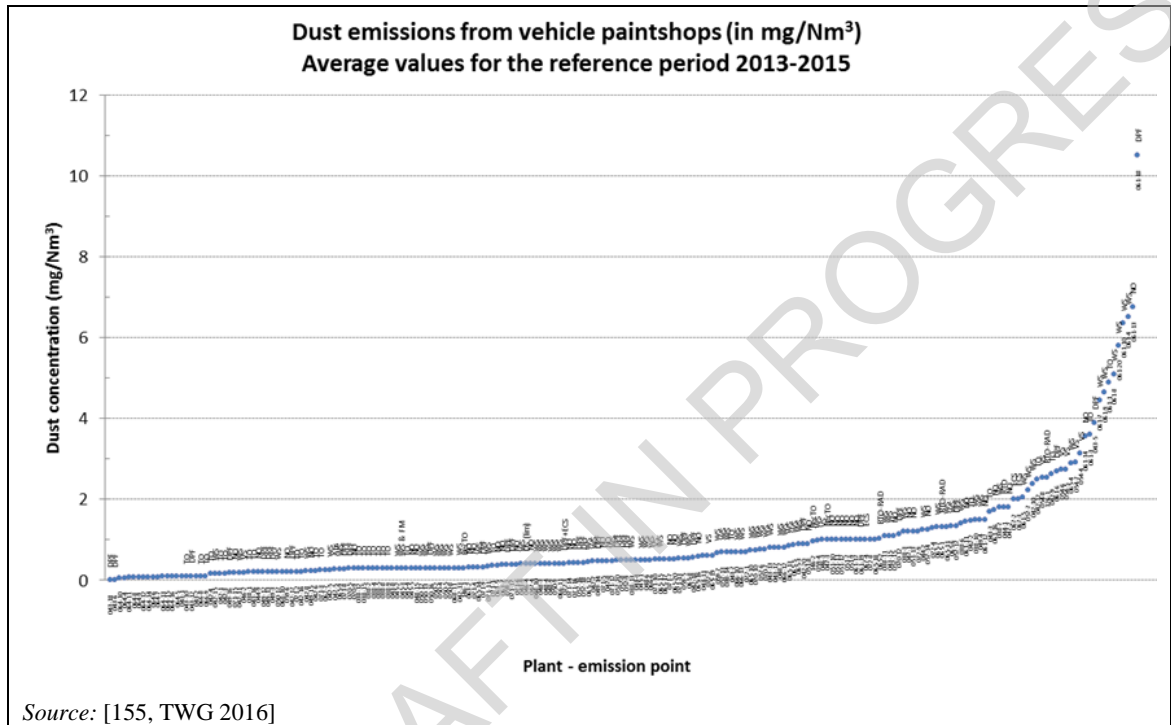


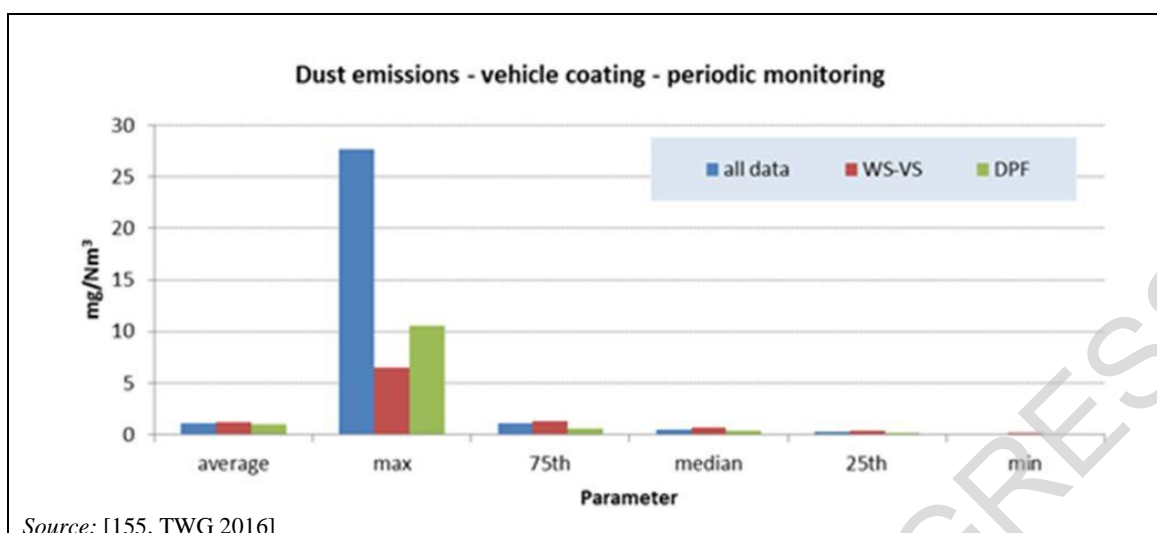
Figure 2.23: Reported values of dust emissions from vehicle paint shops (mg/Nm<sup>3</sup>) (periodic monitoring) - Average values for the period 2013–2015

The statistical analysis of submitted dust emission data in total and per applied abatement technique is presented in Table 2.19 and Figure 2.24.

**Table 2.19: Statistical data from reported dust emissions from vehicle paint shops**

	Applied technique	Continuous monitoring	Periodic monitoring	Continuous monitoring	Periodic monitoring				Continuous monitoring	Periodic monitoring				Continuous monitoring	Periodic monitoring			
		Average 2013–2015	Average 2013–2015	2015				2014				2013						
				Ave.	Ave.	Max.	Min.	Ave.	Ave.	Max.	Min.	Ave.	Ave.	Max.	Min.			
<b>No of points</b>	<b>All data</b>	7	217	3	154	124	121	NA	72	51	51	6	78	41	36			
<b>Average</b>		2.7	1.1	0.9	1.2	2.2	0.8	NA	0.6	0.7	0.4	4.3	0.7	0.6	0.4			
<b>Max.</b>		7.5	27.7	1.9	27.7	52.0	5.1	NA	4.8	4.8	3.2	14.4	3.8	2.1	1.5			
<b>75<sup>th</sup></b>		3.0	1.1	1.2	1.1	1.9	1.0	NA	0.8	0.7	0.5	3.0	1.0	0.9	0.6			
<b>Median</b>		1.9	0.5	0.5	0.5	0.9	0.5	NA	0.4	0.5	0.3	2.5	0.6	0.5	0.4			
<b>25<sup>th</sup></b>		1.6	0.3	0.5	0.2	0.4	0.2	NA	0.3	0.4	0.3	1.8	0.3	0.2	0.1			
<b>Min.</b>		0.4	0.0	0.4	0.0	0.1	0.0	NA	0.0	0.1	0.1	1.4	0.1	0.1	0.0			
<b>No of points</b>	<b>Wet scrubber – Venturi scrubber</b>	3	80	NA	49	50	49	NA	31	23	23	NA	31	18	18			
<b>Average</b>		2.1	1.2	NA	1.4	2.2	1.0	NA	0.8	0.9	0.6	NA	1.0	0.8	0.5			
<b>Max.</b>		3.0	6.5	NA	6.5	12.0	5.1	NA	4.8	4.8	3.2	NA	3.8	1.8	1.1			
<b>75<sup>th</sup></b>		2.5	1.3	NA	2.1	2.8	1.0	NA	0.9	0.9	0.6	NA	1.1	0.9	0.6			
<b>Median</b>		1.9	0.7	NA	0.5	1.0	0.5	NA	0.5	0.6	0.5	NA	0.9	0.8	0.5			
<b>25<sup>th</sup></b>		1.7	0.4	NA	0.3	0.5	0.3	NA	0.4	0.5	0.3	NA	0.6	0.5	0.3			
<b>Min.</b>		1.4	0.2	NA	0.2	0.2	0.1	NA	0.3	0.3	0.3	NA	0.1	0.1	0.1			
<b>No of points</b>	<b>Dry particle filter (DPF)</b>		30	NA	25	16	15	NA	11	6	6	NA	13	3	3			
<b>Average</b>			1.0	NA	1.0	2.2	0.6	NA	0.5	0.4	0.3	NA	0.5	0.4	0.3			
<b>Max.</b>			10.5	NA	10.5	20.0	2.8	NA	1.7	0.5	0.4	NA	0.9	0.5	0.4			
<b>75<sup>th</sup></b>			0.6	NA	0.6	1.2	0.9	NA	0.5	0.5	0.3	NA	0.6	0.5	0.3			
<b>Median</b>			0.4	NA	0.4	0.4	0.2	NA	0.4	0.4	0.3	NA	0.5	0.5	0.3			
<b>25<sup>th</sup></b>			0.2	NA	0.2	0.2	0.2	NA	0.3	0.2	0.2	NA	0.4	0.4	0.2			
<b>Min.</b>			0.0	NA	0.0	0.1	0.0	NA	0.2	0.2	0.2	NA	0.2	0.3	0.1			

Source: 155, TWG 2016



Source: [155, TWG 2016]

**Figure 2.24: Statistical parameters of the reported dust concentration values from vehicle paint shops (periodic monitoring)**

The achieved dust concentration values in waste gases are in general very low with only few elevated values, There is no significant difference in reported values according to the applied dust emissions abatement technique.

The figures in this section are related to the e-coat surface of the car body (see Annex 21.6) where the total surface is typically 65–95 m<sup>2</sup> (mini to medium family car), where primer, base coat and topcoat are applied to about 10–15 m<sup>2</sup> painted surface. Current, average specific emissions of volatile organic compounds for the German car industry is about 35–45 g/m<sup>2</sup> electrocoated surface. It corresponds to an average solvent consumption of 2.5 to 4 kg per vehicle (depending upon each model and individual requirements). Austria estimates VOC emissions of 21–27 g/m<sup>2</sup>, and about 1.8 kg per vehicle with NO<sub>x</sub> 40–80 mg/Nm<sup>3</sup>, CO 25–80 mg/Nm<sup>3</sup>, particles (TPB) <3 mg/Nm<sup>3</sup>. For the European car industry likewise, emission values of between 35 and 45 g/m<sup>2</sup> are achieved, in particular for plants in Sweden and the Netherlands as well as for some plants in Belgium, the United Kingdom, France, Italy, Portugal and the Czech Republic. However, this level has not been achieved for many plants in Europe where the VOC emissions reach values of between 60 and 120 g/m<sup>2</sup>. shows the range of VOC emissions from 65 paintshops in Europe.

For two major companies (one in Sweden and one in Germany), the emissions are substantially lower, down to 10 g/m<sup>2</sup> or below. These are new (or recent) plants using a combination of greenfield sites or complete rebuild, novel green techniques and/or technologies that give finishes that do not meet other manufacturers' quality requirements for finish, durability, chemical resistance, etc. [78, TWG, 2005].

Besides the VOC emissions, paint particles (possibly containing heavy metals) also have to be considered. Particle emissions from overspray are generally well below 5 mg/Nm<sup>3</sup> which is ensured by the use of wet and dry separators within the spray booths.

The efficiency of eliminating VOC emissions is dependent on the techniques used, which include application efficiency, paint VOC content, vapour capture and waste gas treatment, see Section 0. After thermal treatment, cleaned gas concentrations of 10 mg C/m<sup>3</sup> are commonly achieved. A relatively good cost benefit is achieved for the first half of the VOC emissions, often reducing for the rest. The efficiencies of thermal oxidation are 90 % for drying ovens. When combined with carbon absorption, it is 80 % for the primer application, 70 % for the base coat, and 75 % for the clear coat [68, ACEA, 2004, 78, TWG, 2005]. For waste gas treatment in Germany (incineration), emission values well below 10 mg C/Nm<sup>3</sup>, and for NO<sub>x</sub> and CO about

100 mg/m<sup>3</sup> are achieved although the incineration temperature was lowered from 730 to 700 °C and energy consumption was reduced.

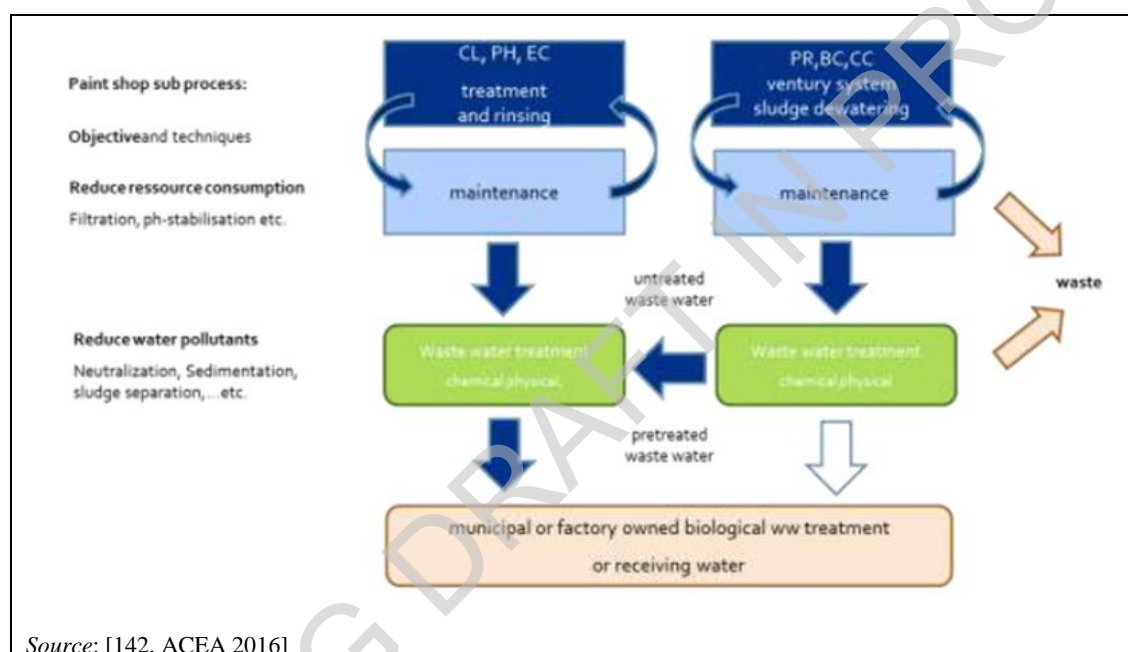
**Figure: Range of VOC emissions from 65 car paintshops in Europe**  
[68, ACEA, 2004]

### 2.3.2.3 Emissions to water

Two types of waste water are produced in a paint shop:

- waste water with inorganic load (salts, heavy metals) from phosphating,
- waste water with mainly organic load (oil, detergents, paint) from cleaning, e-coat and wet scrubber systems.

A typical configuration of waste water treatment in large vehicle paint shops is presented in Figure 2.25.



**Figure 2.25: Typical technical configuration of waste water treatment in large paint shops**

### Waste water from the pretreatment and the immersion prime coating

Most of the waste water originates from the pretreatment of the bodies by degreasing, phosphating, passivation and also from the following electrocoat primer process. The waste waters are predominantly from rinsing the bodies between treatments, therefore removing the materials from the previous process. The components of pretreatment (degreasing), conversion coatings and passivation, as well as the water management and water-saving techniques applicable to all, are described in detail in the STM BREF [59, EIPPCB, 2006]. These include multistage rinsing and techniques to minimise water use and recover water and raw materials, and are equally applicable to electrocoating.

Electrocoating can be operated with multiple (cascade) rinses, with separation and recovery of the paint solids and the liquid (ultrafiltrate) being returned for rinsing. Although rinses are usually carried out in a closed loop for the paint solids, some rinsing water may be lost (containing traces of paint, water-based solvents, etc.) and there is a need for periodic cleaning. ~~At present, Unleaded Electro-immersion paint does not contain lead considered as good~~



practice. However, new potentially risky materials, e.g. organotin compounds (DBTO), arise as a polymerising catalyst in the e-coating process with some lead-free products and may occur in waste water treatment. Other substances in the degreasing and pretreatment waste waters are detergents, pressing oils, ferrous, manganese, nickel and zinc phosphates, fluorides and borates. Cr(VI) is no longer used as a passivation material, due to the ELV Directive strictly limiting Cr(VI) in vehicles (there are exemptions for heavy commercial vehicles). Cadmium occurs in all zinc compounds as a contaminant at 10 mg/kg<sup>15</sup>.

### Waste water from coating processes

Other waste water is generated by the wet cleaning-out of paint overspray as:

- a mix of paint, water and coagulating agent residues;
- a mix of paint, water and solvent generated by cleaning the nebuliser units and paint supply conduits;

During the spraying application of paint in spraying booths, overspray is generated and is caught in wet cleaners. This is required to minimise emissions of paint as particulate matter. The water for these scrubbers is recirculated in a closed loop, and the paint sludge is separated and has to be removed periodically for maintenance. The same methods are used for the separation of both solvent-based and water-based paints.

The organic solvents contained in solvent-based paints are mostly very volatile with low solubility in water. Water-based paints have a substantially smaller solvent proportion which, however, is almost completely soluble in water. If these solvents have a very low vapour pressure, they can accumulate in the water. Solvents for water-based paints accumulate in the water circulating in the spray booth only up to the equilibrium state (usual concentrations are about 0.5 %). The rinsing water of the spray booth is held in a closed loop and is renewed periodically, such as twice a year or less frequently. Moreover, waste water is generated by the cleaning of the heat exchangers of the spray booth exhaust air and the heat rotors as well as by the humidification of the input air supplied to the spray booth [38, TWG, 2004].

The waste water from degreasing and pretreatments is usually treated in a waste water treatment plant (usually but not always at the same site) described in detail in the STM BREF [59, EIPPCB, 2006]. The WWTP may also treat waste waters from other activities on site. The treated effluent may then be discharged directly to surface waters, to a municipal waste water treatment plant or transferred to another industrial waste water treatment plant (on or off site). ~~It may then be discharged to a for further treatment which is, along with emission values associated with BAT.~~

The discharge points and treatments carried out depend on the installation.

A COM study identified the main parameters and other substances of interest that may be discharged in waste waters (including those mentioned above) and therefore to be considered for the data collection<sup>16</sup>. These are given in Table 2.20.

• <sup>15</sup> For example, US and UK Pharmacopias: 10 ppm maximum permitted value in pharmaceutical zinc oxide. See also STM BREF for zinc electroplating, a mix of paint and water generated by cleaning the painting booths.

<sup>16</sup> COM working document EIPPCB 09/06/2016: Assessment of Technical Working Group (TWG) data submitted on metals and other emissions to water for their consideration as Key Environmental Issues for installations carrying out IED Annex 1 6.7 activities.

**Table 2.20: KEIs for waste waters from the coating of passenger cars, vans, trucks and trucks cabs, and buses**

Identified main parameters	Parameters of interest
TSS, TOC/COD, Ni, Zn, Cd, Phenol, AOX, Fluoride, phosphate	DEHP, NP/NPE, NMP
Also, for trucks and truck cabs: Pb, Cr(VI) (authorised restricted usage under REACH)	

Data on waste water emissions from the coating of vehicles were received from 23 installations. The main techniques applied are as described in the STM BREF:

- **In process:**
  - substitution;
  - reverse cascade rinsing.
- **Waste water treatment techniques:**
  - coagulation and flocculation;
  - neutralisation;
  - sedimentation (settlement);
  - filtration (using sand filters).

The reported concentration values for each pollutant are presented in the following figures. The abbreviations presented in

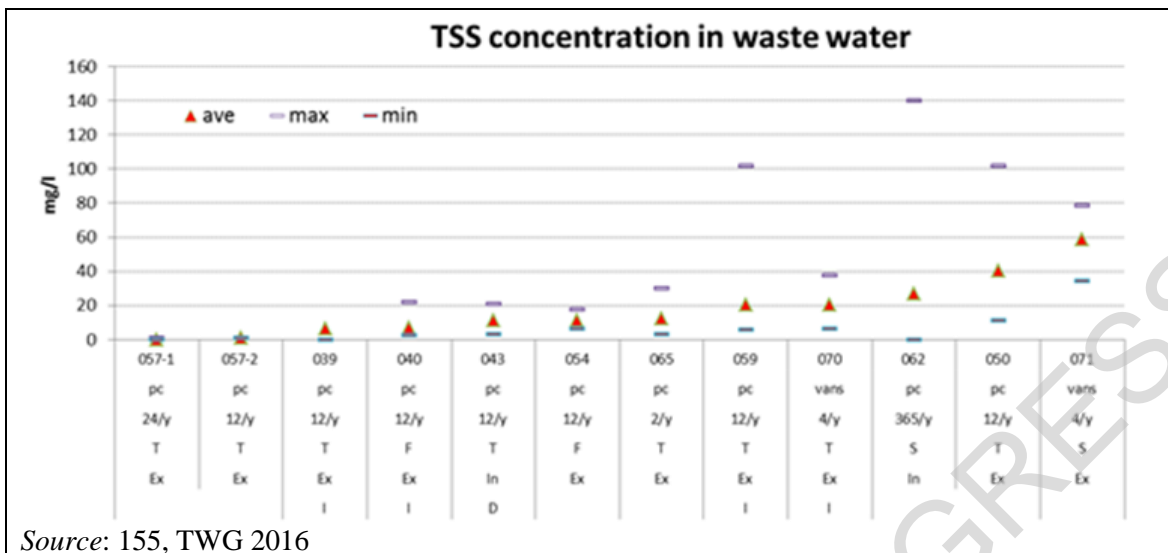
Table 2.21 have been used along the horizontal axes.

**Table 2.21: Table of abbreviations used in plots for the pollutant concentrations in waste water**

Row	Information	Abbreviation used and explanation		
1 <sup>st</sup>	Plant code number and discharge point code number			
2 <sup>nd</sup>	Type of plant – product type ( <sup>1</sup> )	PC: coating of passenger cars	Vans: Coating of vans, trucks and truck cabins	
3 <sup>rd</sup>	Sample frequency	x/yr where x is the number of samples taken per year (e.g. 12/yr means monthly, 52/yr means weekly)		
4 <sup>th</sup>	Sample type	T = Time-proportional	F = Flow-proportional	S = Spot
5 <sup>th</sup>	Monitoring type	E = External		I = Internal
6 <sup>th</sup>	Discharge type	I = Indirect to sewer		D = Direct to receiving water body
<sup>(1)</sup> Please note that no data for emissions in waste water were submitted for bus coating installations.				

### Total suspended solids (TSS)

Data for total suspended solids concentration values were reported for only 11 plants and 12 discharge points. The values distribution is shown in Figure 2.26.



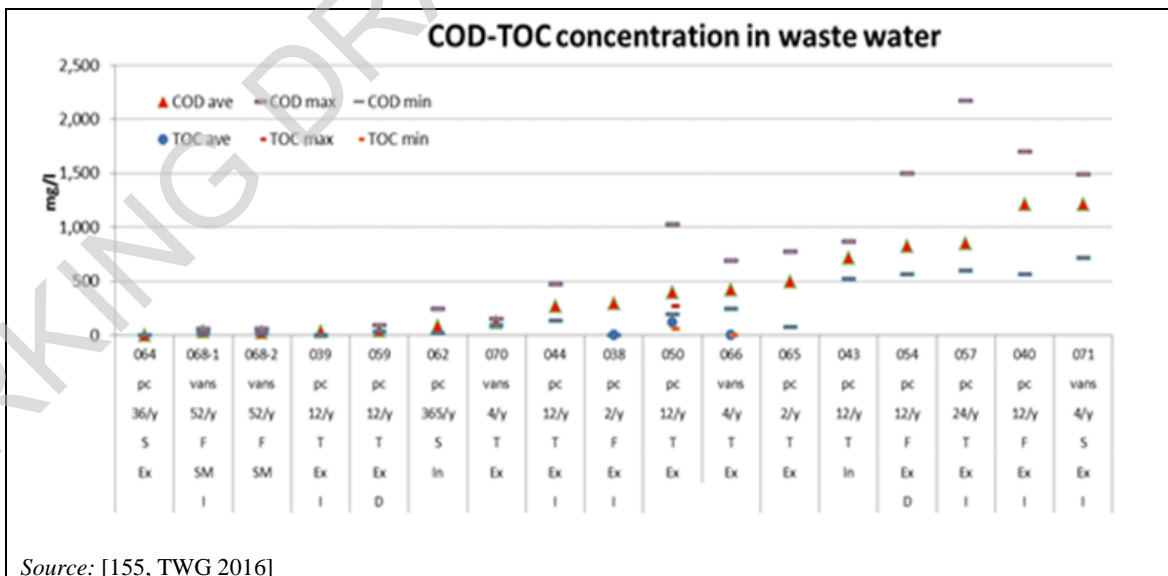
Source: 155, TWG 2016

Figure 2.26: Reported values of total suspended solids in waste water from vehicle coating plants (2015)

The vast majority of reported values (10 out of 12) are lower than 27 mg/l.

### Chemical oxygen demand (COD) and total organic carbon (TOC)

The reported concentration values for COD and TOC are presented in Figure 2.27. Data from 16 plants (with 17 discharge points) were reported for COD concentration values and data from only 3 plants (4 discharge points) were submitted for TOC values. Two additional data sets with extremely high COD values related to internal process monitoring (of the order of 8–35 000 mg/l) are not included in this analysis. The small number of reported TOC values did not allow the examination of a possible correlation between TOC and COD values.



Source: [155, TWG 2016]

Figure 2.27: COD and TOC concentration values in waste water from vehicle coating plants (2015)

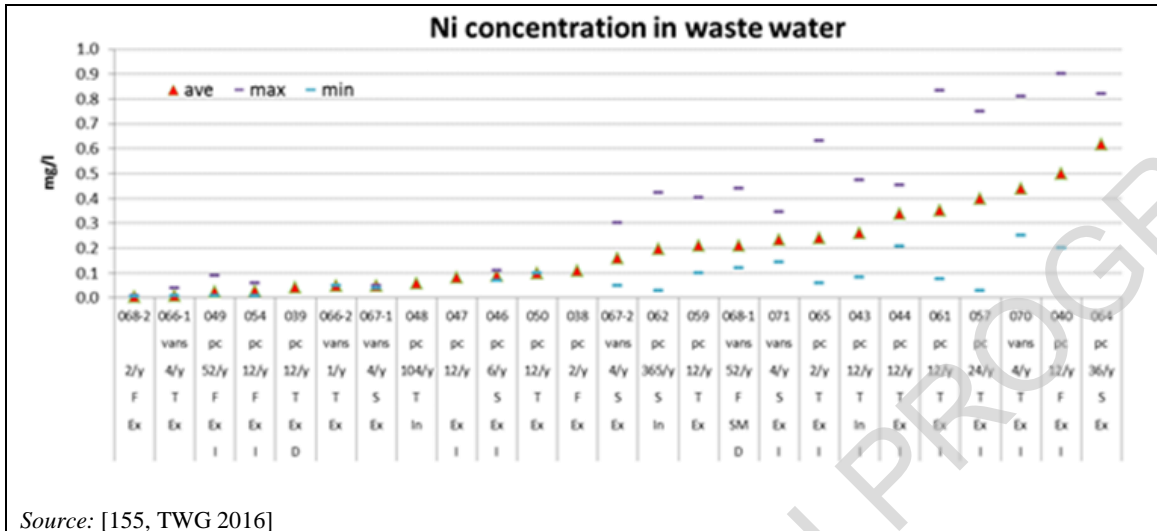
COD concentration values show a large variability with average values up to 1200 mg/l.

### Metal emissions

In the following paragraphs, the reported data and analysis of metal emissions in waste water from vehicle coating plants are presented.

**Nickel (Ni)**

Data on nickel emissions were reported for 22 plants (25 discharge points in total). The distribution of the reported concentration values is shown in Figure 2.28



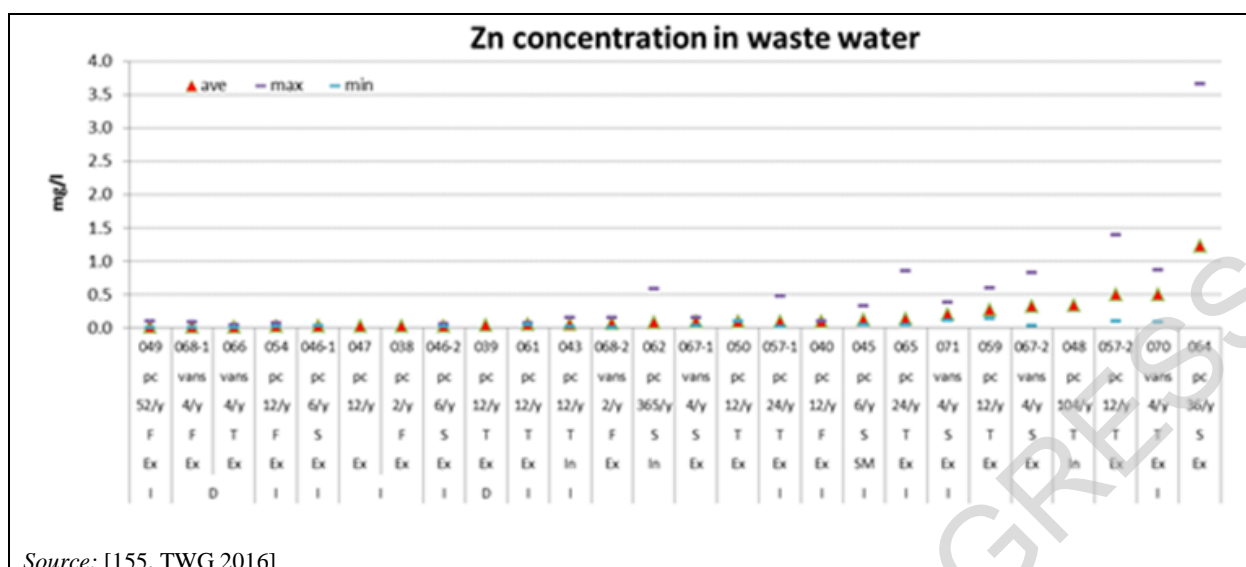
Source: [155, TWG 2016]

**Figure 2.28: Reported values of Ni concentration in waste water from vehicle coating plants (2015)**

There is little information on the method of final discharge (direct to receiving water body or indirect). The sampling frequency varies significantly from yearly to daily. Two installations with the most frequent monitoring (daily and weekly) reported average nickel concentration values of less than 0.2 mg/l.

**Zinc (Zn)**

Data for zinc concentration values in waste water were received for 24 plants (in total 27 discharge points). The distribution of the reported concentration values is shown in Figure 2.29.



Source: [155, TWG 2016]

**Figure 2.29: Reported values of Zn concentration in waste water from vehicle coating plants (2015)**

The achievable concentration levels for the majority of the reported plants are below 0.3 mg/l which includes all plants with frequent monitoring (at least monthly).

### Hexavalent chromium (Cr(VI)) and total chromium (Cr<sub>total</sub>)

A number of sites reported low values for Cr(VI) and Cr<sub>total</sub>. The industry has confirmed:

- hexavalent chromium in vehicles was phased out by 2003, according to the requirements of the ELV Directive<sup>17</sup>.
- where measurements were made, this was based on out-dated permit requirements
- some values were transcription errors, omitting 'less than' (<) symbols
- most values were less than the reported LoD (which may coincide with the permit limit value)

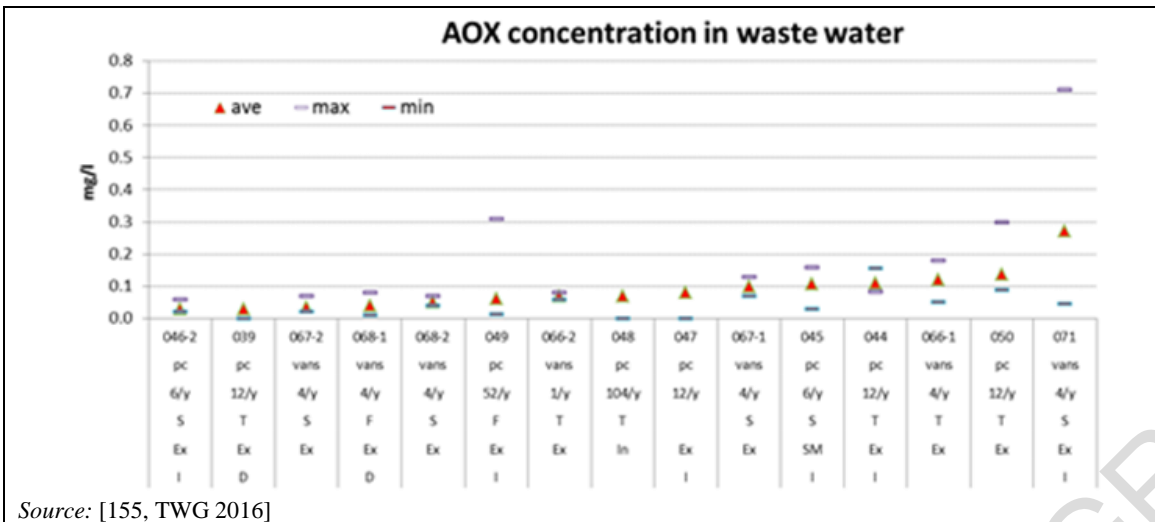
The few trace values may be attributed to one or more of the following:

- samples from waste water streams combined with other activities, including domestic sewage, and other unknown sources
- trace amounts of Cr may be caused by the etching of stainless steel surfaces (e.g. pipes, treatment tanks, car bodies, erosion of stainless steel electrodes in e-coating tanks). However, these have not been studied in detail.

### Adsorbable organic halogens (AOX)

Data for AOX concentration values in waste water were received for 14 plants (in total 16 discharge points). The distribution of the reported concentration values is shown in Figure 2.30. No specific end-of-pipe techniques for reducing AOX emissions were identified.

<sup>17</sup> Directive on End-of Life Vehicle 2000/53/EC

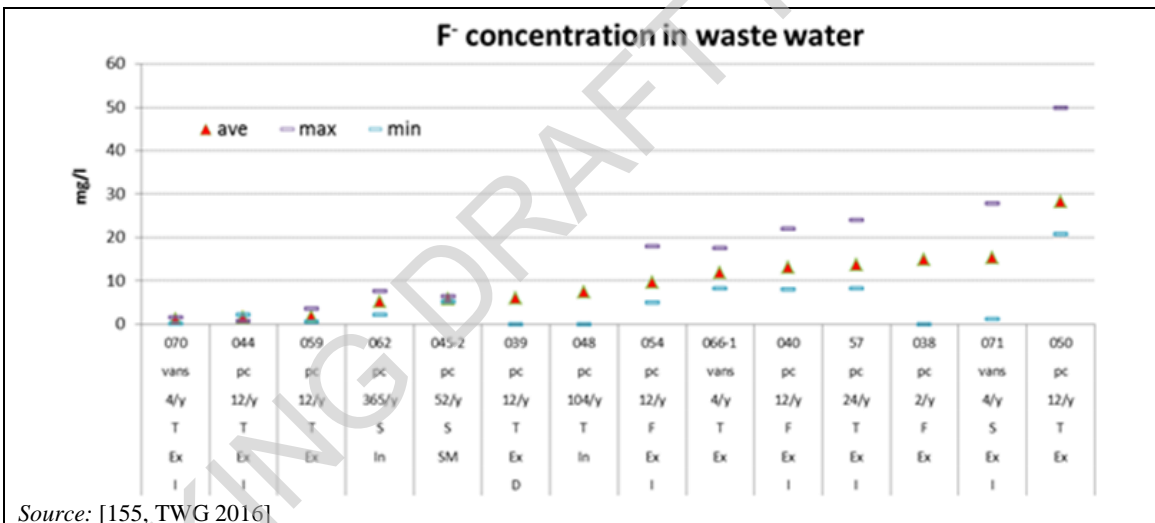


Source: [155, TWG 2016]

Figure 2.30: Reported values of AOX concentration in waste water from vehicle coating plants (2015)

**Fluoride (F<sup>-</sup>)**

Data for fluoride concentration values in waste water were received for 14 plants. The distribution of the reported concentration values is shown in Figure 2.31. All but one of the reported values are lower than 16 mg/l. No specific end-of-pipe techniques were identified for the removal of fluoride.



Source: [155, TWG 2016]

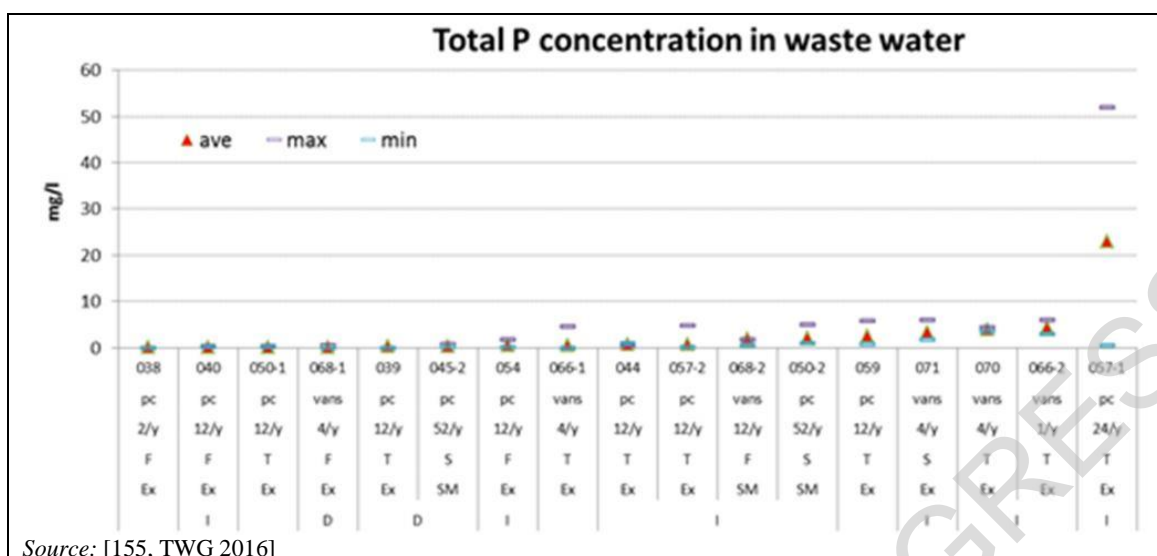
Figure 2.31: Reported values of Fluoride concentration in waste water from vehicle coating plants (2015)

**Total phosphorus (P<sub>total</sub>)**

Data for total phosphorus concentration values in waste water were received for 16 plants (in total 17 discharge points). The distribution of the reported concentration values is shown in Figure 2.32.

All but one of the reported values are below 5 mg/l.

No specific end-of-pipe techniques for reducing total phosphorus emissions were identified.

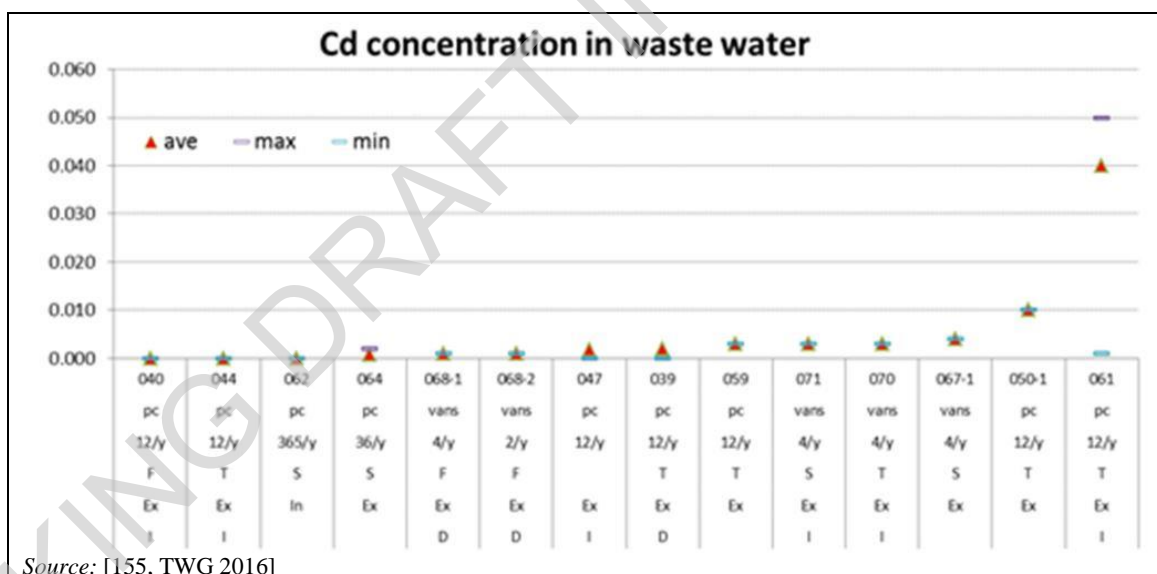


Source: [155, TWG 2016]

Figure 2.32: Reported values of total phosphorus concentration in waste water from vehicle coating plants (2015)

### Cadmium (Cd)

Data for cadmium concentration values in waste water were received for 13 plants (in total 14 discharge points). The distribution of the reported concentration values is shown in Figure 2.33



Source: [155, TWG 2016]

Figure 2.33: Reported values of cadmium concentration in waste water from vehicle coating plants (2015)

Almost all of the reported values are below 0.05 mg/l; only two plants reported higher values, one with a cadmium concentration value of 0.10 mg/l and the other with one of 0.04 mg/l.

No specific techniques are applied to reduce cadmium emissions, as it is a low-level contaminant of zinc compounds.

## Phenol index

Only six plants reported emission concentration values for phenol index, with all the values but two lower than 0.05 mg/l (one of 0.25 mg/l and another one of the order of 3.4 mg/l).

## Water emissions from paint spray booths

These emissions arise from water used to trap paint overspray with venturi scrubbers and, in some cases, the conditioning of the booth air supply and car washing. Insufficient data were submitted in the data collection to propose BAT-AELs.

Techniques used include:

- neutralisation;
- coagulation;
- sedimentation;
- decanter;
- sand filter;
- filter press (for removing water from the sludges produced);
- magnetic separator;
- micro-or nano-filtration.

### 2.3.2.4 Waste generation

[155, TWG 2016] [142, ACEA 2016]

~~Substantial wastes originating from pretreatment/cathodic immersion prime coating and the painting of vehicle bodies include:~~

- ~~• solvent waste: the primary source of solvent wastes are recovered solvents, old solvents, solvent leftovers, used and contaminated cleaning agents are generated, among other things, by the cleaning and setting up of solvent based paint systems, by tool, device or spray booth cleaning and possibly by the waste gas cleaning of painting and drying~~
- ~~• paint leftovers and old paints: due to their changed physical and/or chemical characteristics, paint leftovers and old paints that are no longer usable and have to be disposed of as waste material. Out of specification and/or surplus batches and dried paints are likewise waste. Differentiation can be made between non-cured paint leftovers with solvent content and cured old lacquers/paint residues without solvents. Water based paints and powder coatings are also included~~
- ~~• paint sludge: during spray painting, non separated overspray is captured in water and the coagulated lacquer particles are removed from the water. Coagulation agents are added to the water for separation and for improved cleaning out processes, hence paint sludge is generated~~
- ~~• used adsorption agents: if waste gas cleaning methods are used such as adsorption onto charcoal, solvent loaded charcoal is generated that has to be disposed of~~
- ~~• phosphate sludge resulting from pretreatment~~
- ~~• PVC wastes generated by the application of underbody protection~~
- ~~• filters and filter pads~~
- ~~• used cellulose wipes and cleaning wipes: solvent saturated cellulose and cleaning wipes are generated in cleaning operations of the application devices. They are partly polluted with paint.~~

A mixture of hazardous and non-hazardous waste is generated from vehicle paint shops.

The main types of waste reported are related to:



- waste paint and varnishes which contain organic solvents;
- sludges from physico-chemical processes which contain dangerous substances;
- absorption agents and filtration materials which contain traces of hazardous substances;
- aqueous rinsing liquids which contain dangerous substances;
- phosphating sludge.

Figure 2.34 shows the reported data on the total waste generation (expressed in kg/vehicle) for various types of automotive paint shops. Most of reported waste generation values are below 10 kg/vehicle.

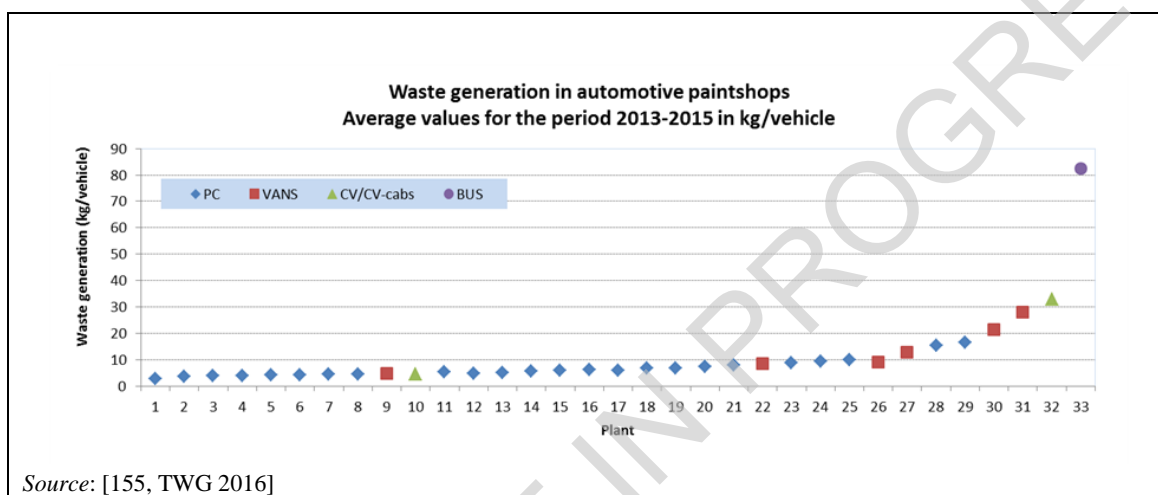


Figure 2.34: Specific values for waste generation (kg/vehicle) in automotive paint shops

The following table summarises the reported data on waste quantities generated at the automotive paint shops per vehicle type.

Table 2.22: Total waste generation data for automotive paint shops

Product type	Reported data <sup>(1)</sup>			Industry report <sup>(2)</sup>		
	# of plants	2015 data (kg/unit)	50 % middle range (kg/unit)	# of plants	2012 data (kg/unit)	50 % middle range (kg/unit)
PC	24	6.6	4.2–7.7	59	4.59	3.16–5.91
VAN	6	14.4	9.0–18.9	8	13.4	7.9–14.0
CV/ CV-cab	2	18.5	NA	CV-cabs:5	7.4	1.6–11.1
				CV: 4	7.47	NA
BUS	1	81.6	NA	6	179	70–155

<sup>(1)</sup> Source: 155, TWG 2016  
<sup>(2)</sup> Source: 142, ACEA, 2016

The main proposed techniques for the reduction of generated waste quantities refer to: the recovery of used solvents (one installation reported an annual recovery of 37 000 kg of solvents); the reduction of the water content of waste, e.g. by using a filter press for waste water sludge treatment; and the reduction of generated sludge and waste by reducing the number of cleaning cycles due to colour changes.

**2.3.2.4.1 Solvent content of waste**

[144, ACEA, 2017]

The submitted data on the solvent contents of the various wastes were analysed for deriving key parameters for the relevant waste types.

The main findings are presented in Table 2.23.

**Table 2.23: Solvent content of main waste types from automotive paint shops**

Type	No of samples		Average	Std. dev.	Min.	Max.	Median	> 25 %	< 75 %
	All	With %	%	% of ave.	%	%	%	%	%
Waste paint	28	18	<b>34.4</b>	66	0.4	70.0	<b>27.5</b>	12.0	50.0
Plastisols, Sealers, Adhesives	16	8	<b>3.0</b>	88	0.0	9.0	<b>2.2</b>	1.2	4.1
Used solvents	59	49	<b>61.7</b>	47	0.9	100.0	<b>65.9</b>	47.3	91.7
• used solvents H	NA	28	<b>93.7</b>	8	75.0	100.0	<b>91.9</b>	88.3	99.8
• used solvents M	NA	5	<b>52.8</b>	7	48.3	57.7	<b>52.6</b>	50.4	54.9
• used solvents L	NA	16	<b>9.6</b>	78	0.0	24.0	<b>9.9</b>	3.3	16.8
Paint sludge	43	26	<b>4.7</b>	172	0.0	40.0	<b>2.0</b>	0.6	3.8
Limestone	2	1	<b>0.2</b>		0.2	0.2	<b>0.2</b>	0.2	0.2
Other (VOCs)	26	9	<b>10.2</b>	128	0.0	30.0	<b>1.5</b>	0.5	24.8
Phosphate sludge	23	2	<b>0.1</b>	NA	0.0	1.5	<b>0.0</b>	0.0	0.0
Other (non-VOCs)	59	1	<b>0.0</b>	NA	0.0	0.1	<b>0.0</b>	0.0	0.0
Not paint-shop-specific	21	2	<b>0.2</b>	NA	0.0	0.2	<b>0.1</b>	0.1	0.2

**Waste paint** is understood as expired paint material or paint which is to be disposed of for other reasons. Its composition resembles the composition of the new material, however small amounts of solvents may be added on site for viscosity adjustment. In some plants, expired paints may be returned to the supplier instead of being sent to a waste disposal facility.

**Plastisols**, like seam-sealing materials, **adhesives** or underbody coats are usually applied after electrocoating and before spray painting operations. Chemically they are macromolecular materials (PVC, PU-, rubber or epoxy-resins, etc.) with different amounts of plasticisers, sometimes with a VOC-like volatility.

Plastisol wastes are either expired material in containers, plastic foils with droppings or stoppers with sticking sealants or underbody coats.

**Used solvents** are usually thinners or organic cleaning agents mixed with different amounts of paint. They are generated and collected at paint change or bell cleaning processes.

The available data show that three subtypes of used solvents with different solvent contents can be distinguished:

- **'H'** high solvent concentration: median 92 %, 50 % mid range: 88 % to > 99 %;
- **'M'** medium solvent concentration: median 53 %, 50 % mid range: 50 % to 55 %;
- **'L'** low solvent concentration: median 10 %, 50 % mid range: 3 % to 17 %.

'H'-type solvents are from clear coat applications or if solvent-based paints are used. 'L'-type solvents are usually butylglycol water mixtures with water-based primer or base coat. If both types of solvents are collected in the same tank, 'M'-type solvents are generated.

**Paint overspray (paint sludge)** from spray painting operations is introduced in waste gas treatment systems for the reduction of the (paint) particle concentration in the exhaust air. Until recently, venturi scrubbers or equivalent wet scrubber systems were used in all large vehicle paint shops. In new paint shops, dry particle filters are installed and paint particles are either captured in pulverised limestone or adsorbed in cardboard filter boxes.

The precipitated paint particles are removed from the water reservoir of wet scrubber systems by coagulation and sedimentation. The primary paint sludge is further dewatered using different techniques, which yield pasty (> 80 % water) or solid (< 40 % water) waste.

Solvent contents are reported to be between 1 % and 4 %, but in some cases higher concentrations are measured or calculated. In one installation (066), paint sludge with a solvent concentration of 40 % was reported, which is most probably either waste paint or a solvent paint mixture from paint change operations.

#### Other solvent-containing wastes

All other solvent-containing wastes fall into this group. There are solvent content data available for some of these wastes and most solvent contents are lower than 5 %, but wax residues from solvent-based cavity preservation have solvent contents between 20 % and 30 %.

#### 2.3.2.4.2 Solvent mass flows in waste (parameter O6 of the Solvent Mass Balance) [144, ACEA, 2017]

From the submitted data, when both the amount of waste and its solvent content are reported and the total body surface of all painted vehicles is known, the waste-specific mass flow in  $\text{g/m}^2$  is calculated. The results of this calculation are shown in Table 2.24.

**Table 2.24: Contribution of solvent containing wastes to the solvent mass flow (parameter O6 of the solvent mass balance)**

Waste type	No of plants	Average	Min.	Max.	Median	> 25 %	< 75 %
		$\text{g/m}^2$					
Other (VOCs)	6	0.18	0.00	0.68	0.0	0.0	0.3
Paint sludge	23	0.91	0.00	8.68	0.3	0.1	0.6
Plastisols, Sealers, Adhesives	8	0.13	0.00	0.33	0.1	0.0	0.3
Waste paint	11	0.70	0.00	4.31	0.3	0.2	0.6
Used solvents	24	8.87	0.10	26.74	5.7	2.8	11.6

The data above indicate the major contribution of used solvents to the total emissions with mass flows between  $3 \text{ g/m}^2$  and  $15 \text{ g/m}^2$  for most of the cases. For most of the reported plants, used solvents carry more than 80 % of all the solvent content in the waste.

## 2.4 Techniques to consider in the determination of BAT for the coating of cars

In Chapter 17, general techniques (i.e. those used that are commonly used) are discussed which might also be applicable to the automotive industry, for categories M1 and N1. In Section 17.7, techniques relevant to paint application are discussed. In Table 2.25, the general techniques relevant for cars that are described in Chapter 17 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

The TFTEI synopsis sheet for the coating of cars [147, TFTEI 2016] provides important data on the costs and benefits at the European level of some techniques for the reduction of VOC emissions. However, the TFTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as compatibility and cross-media effects or of the technical characteristics of individual installations and products [84, EGTEI, 2005] [147, TFTEI 2016].

**Table 2.25: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### 2.4.1 Solvent mass balance of motor vehicle paint shops

[209, ACEA 2017]

#### Description

Solvent mass balances are a tool to calculate total emissions of organic solvents from industrial installations. The results are expressed - in general - as total emissions of x kg organic solvents from the whole installation (E) and - in the case of coating of new motor vehicles - as relative total emissions (Er) in g per m<sup>2</sup> surface area of the products which are painted in this installation. The reporting and averaging period is twelve months for demonstration the compliance with emissions limit values (ELV) based on BAT-AELs. SMBs may be calculated for shorter intervals, e.g. as internal management tool to identify process deviations that may lead to a violation of the ELV.

Detailed description can be found in Annex 21.6

## 2.4.2 Coating systems (Paint shop type, 'paint shop family')

[143, ACEA 2017]

The basis for four types of paint shop families are explained in Sections 2.2.4.8 and 2.2.4.9.

The technical difference between SB and WB paint shops are demonstrated in 2.2.4.8, which demonstrates that changing from SB to WB is far more complex and costly than a simple substitution.

A study to establish the costs and benefits of different approaches to VOC abatement in the coating of passenger cars considered the four paint shop families which covered 70 out of 74 existing high-volume car paint shops: SB, SB-MIX, WB and Integrated (there are two options in SB-MIX paint shops, see Section 2.4.2.1) [147. TFTEI 2016].

An SB paint shop can be regarded as the 'conventional' case, as it is unlikely that a new paint shop being built, or an existing paint being rebuilt, would be SB. Data and information on SB paint shops are included for comparison purposes. An average value of 37.8 g/m<sup>2</sup> is reported. The reported range is 16.8–50.3 g/m<sup>2</sup>, however the basis for the lowest figure is not clear.

Solvent emissions can be reduced by applying in-process (primary) and end-of-pipe (secondary) measures.

*Further information, including on costs and benefits to be added from the TFTEI study [147, TFTEI 2016] and from the data needs to be clarified*

### 2.4.2.1 Solvent-water mix (SB-MIX) coating system

#### Description

Coating system where one coating layer (primer or base coat) is water-based.

#### Technical description

Where these changes are implemented, they are most frequently restricted to only one subprocess (primer or base coat). This type of paint shop is then called an SB-MIX paint shop.

#### Achieved environmental benefits

#### Environmental performance and operational information

An average value of 28.7 g/m<sup>2</sup> is reported. The reported range is 12.5–48.2 g/m<sup>2</sup>, however the basis for the lowest figure is not clear.

Solvent emissions can be reduced by applying in-process (primary) and end-of-pipe (secondary) measures.

#### Cross-media effects

No information provided

#### Technical considerations relevant to applicability

No information provided

#### Economics

No information provided

#### Driving force for implementation

No information provided

### Example plants

Approximately 20 paint shops in the EU (2014).

### Reference literature

[147, TFTEI 2016]

## 2.4.2.2 Water-based (WB) coating system

### Description

Coating system where the primer and base coat layers are water-based.

### Technical description

#### Achieved environmental benefits

Reduction in solvent usage and emissions from the process.

#### Environmental performance and operational information

An average value of 18.6 g/m<sup>2</sup> is reported. The reported range is 6.0–30.5 g/m<sup>2</sup>, however the basis for the lowest figure is not clear.

Solvent emissions can be reduced further by applying in-process (primary) and end-of-pipe (secondary) measures.

#### Cross-media effects

Potentially increased energy consumption. *To be clarified from existing information and with TWG.*

#### Technical considerations relevant to applicability

In existing sites, changing from the SB family to the WB family can only be done if there is enough room to build a second paint shop (or paint shop line) in parallel without interrupting the existing one.

#### Economics

Switching the primer and the base coat from solvent-based (SB) to water-based (WB) coating (data from one plant):

- Investment cost: EUR 128 million;
- Annual cost: EUR 11.5 million/year;
- Cost per unit: EUR 0.593/year/m<sup>2</sup>;  
EUR 0.579/year/car body.

#### Driving force for implementation

No information provided

### Example plants

Approximately 32 paint shops in the EU (2014).

### Reference literature

[147, TFTEI 2016]

## 2.4.2.3 Integrated paint shop coating system

### Description

A coating system that reduces energy consumption by:

- reducing drying and curing by using either:
  - a base coat type which combines the functions of primer and base coat; or
  - wet-in-wet-in-wet processes (3-wet)
- dry separation of overspray in combination with spray booth air recirculation.

#### Achieved environmental benefits

Significant savings in space and energy consumption.

#### Environmental performance and operational information

Without additional VOC emission reduction measures, 20.5 g/m<sup>2</sup>. Range given is 8.9–32.1 gm/m<sup>2</sup>, however, the basis for the lowest figure is not clear.

#### Cross-media effects

No information provided

#### Technical considerations relevant to applicability

Due to multiple technical constraints, these integrated processes are difficult to install in existing installations.

#### Economics

Change for a new paint shop (SB) to integrated process (data from two plants):

Switching the base coat from solvent-based to water-based coating and remove the primer:

- Investment cost: EUR 52.7 million;
- Annual cost: EUR 4.7 million/year;
- Cost per unit: EUR 0.244/year/m<sup>2</sup>;  
EUR 0.237/year/car body.

#### Driving force for implementation

Energy and space saving.

#### Example plants

Approximately 12 paint shops in the EU (2014).

#### Reference literature

[147. TFTEI 2016]

~~The paint process in the vehicle manufacturing industry is a highly complex and fully integrated operation consisting of many interdependent steps. As each step influences all others, decisions made about one step can impact on all or part of the process. Equally, some combinations of techniques may be incompatible with each other. Also, an existing application system may limit the choice of coatings. Therefore, when considering techniques for determining BAT, it is not meaningful to select each step separately.~~

~~For instance, various examples of combinations of techniques are given in below. These configurations are intended to be informative and are not to be considered the only options:~~

Example	Primer	Base-coat	Clear-coat
A	<ul style="list-style-type: none"> <li>● SB</li> <li>● WB</li> <li>● None</li> <li>● Powder Primer</li> </ul>	<ul style="list-style-type: none"> <li>● WB</li> </ul>	<ul style="list-style-type: none"> <li>● WB</li> <li>● Powder</li> <li>● Powder slurry</li> </ul>
B	<ul style="list-style-type: none"> <li>● WB</li> </ul>	<ul style="list-style-type: none"> <li>● WB</li> </ul>	<ul style="list-style-type: none"> <li>● SB</li> </ul>

€	● SB	● WB	● SB
	● SB with booth air abatement	● SB	● SB with booth air abatement
	● WB	● SB with booth air abatement	
Key: SB = solvent based, WB = water based			

Table: Examples of combinations of coatings for cars  
[67, ACEA, 2005]

#### 2.4.2.4 Wet-on-wet coating (3-Wet)

##### Description

Wet-on-wet coating replaces a conventional three-coat (primer, base coat, clear coat) two-bake (primer, topcoat) process with a process where materials are applied wet on wet onto the previous layer with one final bake at the end.

##### Technical description

In conventional two-coat top coating, a primer coat is applied and then baked in an oven, before a colouring base coat is applied then subsequently covered with clear coat and baked again.

Different types of wet-on-wet application can be realised:

- Wet-on-wet coating can be realised in both water-based and solvent-based base coat technologies.
- Some installations utilise a conventional primer-type first layer.
- Some installations utilise a functional base coat first layer. A functional base coat layer combines the functional properties of a primer layer but has the appearance properties of the base coat layer which will be applied over it.

##### Achieved environmental benefits

The environmental benefits vary depending on the process and materials used prior to any conversion.

The primer oven is no longer required to bake the primer layer. However, in a wet-on-wet process any body sealer, wet applied NVH material or anti-stonechip material should be fully cured prior to entering the wet-on-wet application. Therefore during some conversions to wet-on-wet application, where only a sealer gel oven is used, a sealer bake oven is required to fully cure these materials before the wet-on-wet application.

##### Example plants

Ford, Europe – Solvent-based High Solids.  
BMW, Europe Water-based IP2 process.

#### [Conventional solvent-based materials]

**Description:** Conventional solvent based paints have the following solvent contents by weight: 35–45 % for primers, 40–50 % for top coats, and 30–35 % for high solid topeoats, 70–80 % for base coats and 50–55 % for clear coats. The solvent (mainly VOC) is present for viscosity, film formation and reduced energy evaporation.

The application involves a closed delivery system to an application gun. Application can be both manual or automatic (or both) in a purpose built spray booth with downdraft and exhaust ventilation.

**Achieved environmental benefits:** Compared to water based paint systems, direct energy requirements for each car is 15 % lower (990 MJ/car compared to 1100 MJ/car for water based



coatings) due to the better climatisation and accelerated flash off of solvent based systems. However, this does not include energy consumption for abatement of spray booth exhaust air which is about 200 to 400 MJ/car. See Section 0 and:

**Cross-media effects:** As a baseline, all solvent materials without emission controls 20 to 30 years ago resulted in 100–300 g/m<sup>2</sup>. Modern systems achieve 43–72g/m<sup>2</sup> for a primer/base coat/clear coat system.

Typically, the solvents in the waste gas from ovens are incinerated as they account for about 15 % of the total VOC emissions from a site using conventional paint systems. Where possible, the heat generated energy is recovered and used, e.g. for heating the driers. However, to achieve low levels, thermal treatments need additional fuel, see Section 0.

**Operational data:** Curing times are shorter than those required for water based systems, therefore, faster line speeds can be achieved in smaller areas due to reduced oven times. Solvent based systems can also operate over a wider temperature and humidity range. Stainless steel equipment is not required.

Modifications to solvent based operations to achieve lower VOC emissions can be achieved with reduced downtime (as opposed to a refit needed with a material change).

This technique does not meet the lower emission requirements necessary in some parts of Europe, and will not achieve even mid-range performance, e.g. as indicated in

**Applicability:** Solvent based paints can be used in all phases of the painting operation (primer, solid topcoat, base coat, clear coat and repair), and can be used on metals and plastics. They can be applied to new and existing paintshops where space is limited and where changes in the paint materials may not be technically possible.

**Economics:** No data submitted.

**Driving forces for implementation:** Economic and technical restraints on existing paintshops may make conventional solvent technology a preferred option for certain facilities.

**Example plants:** No data submitted.

**Reference literature:** [68, ACEA, 2004] [38, TWG, 2004] [78, TWG, 2005]

## 2.4.3 Substitution of solvent-based materials

### 2.4.3.1 Water-based paint systems

#### Description

Water-based paints have a low content of VOCs. They are used as electrocoat, primer and base coat.

See Section 17.7.2.2 for a general description of water based paint systems. In electrocoating, the application of water dilutable or water dispersible paints use materials with a solvent content of 1–6 % and usually 1–2 wt %.

#### Technical description

For automobile volume paint shops, water-based paints are used as an electrocoat, primer or base coat.

In electrocoating, the application of water-dilutable or water-dispersible paints uses materials with a solvent content 2–4 %. Electrocoating materials are delivered in a closed system and applied using dipping techniques.

Conventional water-based systems contain the following solvent contents: 5–12 % in the primer and 12–17 % in the base coat. Primer and base coat materials are delivered in a closed system and applied using spraying techniques.

Water-based paints contain water as the main solvent plus organic co-solvents. Binder systems used are polyurethanes, polyesters, acrylates and melamine resins. The organic co-solvents are necessary for achieving qualities such as optimum spread properties, dissolving capacity and adherence of different substrates as well as a sufficient application window.

~~Electrocoating materials are delivered in a closed system and applied using dip techniques. For primer and base coat applications, water-based paints contain water dilutable or water dispersible film forming agents (alkyd, polyester, acrylate, melamine and epoxy resin). Primer and base coat materials are delivered in a closed system and applied using spray techniques. Conventional water-based systems contain the following solvent contents by weight: 5–10 % for primer and 10–15 % for base coat.~~

### **Achieved environmental benefits**

The main advantage of water-based paints is the reduction of VOC emissions.

Typical VOC emission factors for the water-based phases of the paint shop include 0.6–1 g/m<sup>2</sup> for the electrocoat, 0.5–2 g/m<sup>2</sup> for the primer and 3–7 g/m<sup>2</sup> for the base coat with no emission controls.

Cleaning of spraying devices and other tools can be carried out with water/solvent mixtures with a solvent proportion of about 5–20 %. In some cases, the cleaning material can be solvent-free.

Another advantage is that there are no flashpoint hazards associated with this paint, minimising the risks of combustion and explosion.

~~Typical VOC emission factors for the water-based phases of the paint shop include 1–2 g/m<sup>2</sup> for the primer, 6–8 g/m<sup>2</sup> for the base coat (7–9 % for products with reduced flash-off time; see Section 0 and 2-component types) with no emission controls.~~

### **Environmental performance and operational information**

No information provided.

### **Environmental performance and operational data** *TWG please confirm any of this is still valid*

Energy requirements are typically 1100 MJ per car. For data on specific processes, see Section 2.3.1.1. Influences on operations: production volume, local climatic conditions, abatement techniques used, air volume requirements, length of booths, booth operating criteria such as temperature and paint application techniques.

### **Cross-media effects**

Compared to organic solvents, water has higher evaporation energy. Therefore, the energy demand for the drying of water-based paints may be expected to be higher if the same drying rate as for solvent-based paints has to be achieved. However, compared to atomisation, acclimatisation of spray booths, heating of substrates, oven losses, etc., the energy demand for evaporation of volatile compounds is only in the range of 1–2 % for many industrial processes. Water, instead of organic solvents, has a minor impact on total process energy. The additional energy requirement is only significant for drying in ambient conditions.

~~The direct energy requirements per car are approximately 13–17 % more than solvent operations partly due to the requirement to dry each layer between coating applications (intercoat flash-off).~~

Energy generation from some solvent incineration systems is lost.

Material consumption for waterborne material has been reported to be comparable to solvent-based paints between 0 and 11 % higher for primer and between 0 and 25 % higher for base coat.

Water consumption is also higher and the sludge separation in waste water treatment is more difficult.

### Technical considerations relevant to applicability

Waterborne materials can be used as the electrocoat, primer and base coat and in some repair operations. They can be used on metals and plastic materials. They are widely used. Due to the permanent development of these materials, their range of application is steadily increasing.

However, they cannot be used with one coat one bake solid colours as they would need to be sealed with a clear coat. Waterborne materials have been developed for clear coat applications, but have not been taken up widely for cars due to their poor appearance and quality. However, note that limitations of appearance and quality of topcoats is independent of whether they are water based or solvent based, but depends on resin technology (alkyd or acrylic) and pigment stability under UV light impact (for example, solvent based alkyd topcoats have poor appearance).

Waterborne solid colour topcoats have been used commercially for years for commercial vehicles and drivers cabs. In one case, a light commercial vehicle is painted with a water based one coat layer without an additional clear coat.

**TWG please confirm any of this is still valid**

There are difficulties in retrofitting waterborne systems into conventional solvent-based paint shops due to cost and physical constraints. The need for extended ovens with intercoat flash-off zones to meet additional curing requirements means that paint shops designed and installed for solvent-based systems may not have the space to accommodate a water-based system. Other requirements are that the paint supply pipes and systems are in stainless steel. Additional costs associated with the operational requirements, materials and equipment installation mean that water-based systems are often restricted to new paint shops, or those already equipped with the necessary systems. Water-based booths have to operate under tighter temperature and humidity controls. Because curing times are longer for water-based systems, the line speed is usually slower than for other systems.

### Economics

Costs for changing existing automated painting lines may be very high in some cases. There are difficulties in retrofitting conventional solvent-based paint shops into waterborne systems due to cost and physical constraints. The need for extended ovens with intercoat flash-off zones to meet additional curing requirements means that paint shops designed and installed for solvent-based systems may not have the space to accommodate a water-based system. Other requirements are that the paint supply pipes and systems are in stainless steel. Retrofitting is usually done at the end of the technical lifespan of the existing installation.

Due to the increased volumes used, water-based paints have become cheaper than solvent-based paints.

Material costs for waterborne paints are 0–20 % higher compared to solvent-based paints, depending on economies of scale. In one of the reference plants (below), no cost difference is seen. Associated energy costs are higher than solvent based materials due to extended drying requirements. Water based technology cannot be fitted into conventional paint shops without significant investment associated with equipment installation and building costs. For example, in large paint shops (over 100000 units per year) typical costs for a complete new spray booth

installation would be between EUR 15 million and 35 million; costs for water-based spray booths may be 10–20 % higher. These figures do not include building costs, which can be substantial depending on local conditions. This, combined with technical constraints, means that water-based technology is usually only fitted during major upgrades or in new paint shops. Since 1994, most new paint shops in EU countries have been designed for waterborne base coats. Retrofit products are available in the form of base coats with reduced flash-off time (see Section 0).

Overall costs, when taking into account decreased abatement costs, are typically lower for waterborne coatings.

### **Driving force for implementation**

Reduction of VOC emissions to the air.

Possible reduction in WGT.

### **Example plants**

All Volkswagen plants in Europe; Renault, Flins sur Seine, France; GM, Eisenach, Germany; Opel, Eisenach, Germany.

### **Reference literature**

[68, ACEA, 2004] [13, DFIU and IFARE, 2002] [78, TWG, 2005] [183, ACEA 2017]

## **2.4.3.2 Powder coating – conventionally cured**

### **Description**

Solvent-free coatings consisting of powder with a particle size in the range of 25–60 µm. Powder coatings are cured in conventional (convection) high-temperature ovens

### **Technical description**

Powder coatings are solvent-free systems that require electrostatic application procedures and are, therefore, primarily suitable for metal bodies. Powder coatings are typically based on acrylic resins with either an acid or an anhydride. They can be used in primer or clear coat applications. Powder application takes place in a purpose-built spray booth with downdraft and exhaust ventilation and can be by automatic electrostatically assisted spraying or manual spraying applications. See also Section 17.7.2.8.

### **Achieved environmental benefits**

- Almost free of solvent emission.
- Low waste generation.
- Application of electrostatically assisted spraying reduces recapture of overspray paint particles by water.
- Simplification of cleaning of tools and booths (vacuum cleaning, compressed air).
- High application efficiency

### **Environmental performance and operational information**

Powder coat technology has zero VOC emission and does not require water use for particulate abatement. The use of reclaimed powder enables material reuse of up to 97 %. Energy requirements are lower than waterborne material and are comparable with solvent-based technology. Drying by combinations of infrared and air circulation drying techniques reduce energy consumption.

There are possible health risks due to use of some mutagenic substances.

### **Cross-media effects**

- Loss of energy generation due to solvent incineration. ~~is omitted.~~
- High curing temperatures are required.

### Technical considerations relevant to applicability

Only one plant was in operation in the European industry in 2007.

In general, colour and finish does not meet most European manufacturers' quality standards.

The powder paint technique allows reduced reprocessing of the booth air compared to conventional installations. There have been problems with a yellowish colouration of the clear coat application in the final product. The main problem is that control of the film thickness is difficult: a greater layer thickness will be created than is necessary (approximately 65 µm), which results in higher paint consumption; however, increasingly nowadays, thinner layers (approximately 55 µm) are also achievable.

Experience from Plant PSA Groupe Mulhouse shows that, after many years of testing, quality levels did not reach quality standards expected by European customers. The price of powders never falls because of lack of deployment (only few production lines in Europe). The viability of installations remains below conventional levels of other painting production lines.

It has also been found that lines without the primer coat step (Integrated Paint Process IPP2) give better results than the powder production line, in terms of economics and/or quality level. The overall VOC emissions of the two technologies are within a similar range.

### Applicability

~~Powder coat technology is currently applicable for primer and clear coat application. Powder primers are now available and used in one plant in Europe (with up to five to six coloured primers). Powder clear coat is used in Europe by one car manufacturer.~~

### Economics

When changing from existing solvent technology to retrofitting powder technology, high capital costs are involved, because powder technology is a completely different technology and requires a total refit of facilities, equipment and materials. However, a reduction of operating costs can be observed; present estimations describe a reduction of at least 12 % in energy costs over either water-based or solvent-based with abatement costs.

### Driving force for implementation

- Reduction in costs due to reduced VOCs and waste water treatment.
- Reduced waste costs.

### Example plants

BMW AG in Dingolfing, Germany *TWG: has the use of powder coat stopped here?*

No information provided, but implemented in PSA Plant Mulhouse *TWG: has the use of powder coat stopped here?*

### Reference literature

[68, ACEA, 2004] [13, DFIU and IFARE, 2002] [27, VITO, 2003] [38, TWG, 2004] [78, TWG, 2005] [ACEA 2017]

### Powder slurry coating

*ESVOC: This technique is obsolete in this sector*

~~**Description:** Powder slurries are powders dispersed and stabilised in water and are applied using conventional equipment for liquid paints. They can be used in clear coat applications.~~

~~**Achieved environmental benefits:** Significant reduction in VOC emissions. Significant energy savings are achieved by replacing the conventional 2 component clear coat by the wet on wet applied powder slurry clear coat. With the wet on wet application, the intermediate drying step can be missed out.~~

**Cross-media effects:** Energy generation due to solvent incineration is omitted.

**Operational data:** To meet the quality criteria, the spray booth must operate under tight temperature (20–24 °C) and humidity (65–75 %) controls. A thinner film (45 µm) can be achieved compared to dry powder coating.

The powder slurry clear coat, which has been in use at DaimlerChrysler AG since 1997, is almost solvent free and is applied by using the wet on wet application technique.

**Applicability:** Powder slurry is not employed in general industrial processes for vehicle coating, although two leading suppliers offer powder slurry systems. Powder slurry requires the application of an adapted colour coat layer to ensure wet on wet compatibility. Before powder slurry can be baked, water must evaporate from the wet film, therefore, a forced flash off is required. It is used in two plants in Europe.

**Economics:** No data submitted.

**Driving forces for implementation:** Reduced VOC emissions.

**Example plants:** DaimlerChrysler AG (Austria) and Rastatt (Germany).

**Reference literature:** [68, ACEA, 2004] [13, DFIU and IFARE, 2002] [38, TWG, 2004].

#### 2.4.4 Paint application techniques and equipment

The following paint application techniques and equipment are commercially applied:

- paint application by immersion, see electrocoating description in Section 2.2.4.2.1;
- ~~conventional high and low pressure spraying;~~
- high-volume low-pressure spraying (HVLP), see Section 17.7.3.12;
- electrostatic atomising spraying processes, see Section ;
- electrostatically assisted high rotation discs and bells, see Section 17.7.3.13;
- electrostatically assisted compressed air, airless and air-assisted spraying, see Section 17.7.3.14.
- powder coatings—electrostatically assisted spraying, see Section 0.

##### **Paint application by immersion**

*Replaced by electrocoating description in Section 17.7.2.3, see bullet points above.*

**Description:** ~~Pretreated vehicle bodies are electrically charged while being passed through a bath of electro immersion coating. The coatings are typically water based and are diluted with deionised water. The solvent content is typically in the range 2–6 wt %, and usually 1–2 wt %.~~

The dip electrocoating process covers all vehicle surfaces interior and exterior. The calculated e-coat area is typically between 60 and 100 m<sup>2</sup> per vehicle, depending on size and design (see Annex 21.6). See also Section.

**Achieved environmental benefits:** Due to the low solvent content of this material and the fact that the material is not atomised as with spray operations, VOC emission levels are very low. Typical emissions are <0.2 kg VOC/car, which equates to between 2–4 g VOC/m<sup>2</sup>, depending on the electrocoated surface area of the car being painted. With abatement of waste gas from the oven, >1 g VOC/m<sup>2</sup> can be achieved.

In addition to the paint consumption being low, a small amount of waste is generated. Dip coating represents a very high application efficiency and because of the low material usage generates very little waste.

**Cross-media effects:** No data submitted.

**Operational data:** Application takes place in a purpose built facility with exhaust ventilation. The primed bodies must pass through an oven before subsequent coatings are applied.

**Applicability:** This technique can be used for whole vehicle bodies and metal components including surface panels that are difficult to reach. At present, the immersion technique is widely used, but only for the application of the primer (cataphoretic application). The optical quality of the lacquer finish is very important in car production, therefore only spraying techniques are used for the application of fillers and topcoats.

**Economics:** No data submitted.

**Driving force for implementation:** Quality and corrosion protection.

**Example plants:** No data submitted.

**Reference literature:** [68, ACEA, 2004] [13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

## 2.4.5 Spray booths

The following techniques are commonly applied:

- wet separation spray booths, see Section 17.10.4.1;
- water emulsion techniques in spray booths,
- recycling of wet scrubber/venturi scrubber effluent, see Section 17.4.1.5.

## 2.4.6 Minimisation of raw material consumption

The following techniques are commonly applied:

- batch painting/colour grouping, see Section 17.6.3.1;
- pig-clearing systems, see Section 17.2.4.4;
- robot application of coatings and sealants, see Sections 2.2 and 17.2.5.

### 2.4.6.1 Low-loss paint change and purge systems

[TWG please provide additional information]

#### Technical description

Coloured coats (mainly base coats) require colour changes. Colour blocks are often less than two cars on average. Even when the best techniques for recovery are in place, purging/rinsing of bells and guns contributes significantly to emissions when solvent-based paints are used. For water-based coats, purge liquids usually comprise 90 % water [38, TWG, 2004].

#### Achieved environmental benefits

No information provided

#### Environmental performance and operational data

No information provided

### **Cross-media effects**

No information provided

### **Technical considerations relevant to applicability**

No information provided

### **Economics**

No information provided

### **Driving force for implementation**

No information provided

### **Example plants**

No information provided

### **Reference literature**

No reference literature provided.

## **2.4.6.2 Recovery of used solvents**

### **Description**

See Section 17.12.2. Modern paint supply equipment including recovery of the purge solvents are commonly applied. Recovery is by piping the cleaning agents from the application equipment to the storage tanks.

### **Achieved environmental benefits**

Typically 80–90 % cleaning and purge solvents can be recovered, either on site or off site, for reuse.

### **Cross-media effects**

No information provided.

### **Environmental performance and operational data**

No data submitted.

### **Technical considerations related to applicability**

No information provided.

### **Economics**

The installation of a typical solvent recovery system costs **EUR 0.4 million** per spray booth.  
*TWG please update*

A saving will be achieved because of a reduced consumption of solvents and reduced amounts of hazardous waste. In large plants, the savings will approximately outweigh the investment.

### **Driving force for implementation**

No information provided.

### **Example plants**

Ford, Europe.

### **Reference literature**

[4, Intergraf and EGF, 1999] [13, DFIU and IFARE, 2002] [26, CITEPA, 2003] [68, ACEA, 2004, 38, TWG, 2004]



## 2.4.7 Drying techniques

The following techniques are commonly applied:

- drying via circulating air with or without dehumidified air, see Section ;
- infrared radiation curing, see Section 17.8.3.1.

## 2.4.8 Waste gas extraction and treatment

The following techniques are commonly applied:

- venturi system, see Section 17.10.4.1;
- wet impact panel scrubber, see Section 17.10.4.1;
- dry filter systems, see Section 17.10.4.1;
- electrostatic filter, see Section 17.10.4.4;
- internal solvent concentration as the pre-procedure for waste gas treatment, see Section 17.10.3.1;
- external solvent concentration as the pre-procedure for waste gas treatment, see Section 17.10.3.3;
- dedicated waste gas treatment system integrated in the dryer, see Section 17.10.1.1.1;
- adsorption: fixed-bed adsorption, fluidised bed adsorption and rotor (wheel) absorption, see Section 17.10.6.3;
- oxidation: recuperative, catalytic, and regenerative oxidation, see Section 17.10.5.

### 2.4.8.1 Enclosed application zones

#### Description

Coatings with solvents are applied in enclosed application zones with dedicated ventilation and waste air collection systems.

#### Technical description

##### Overview

A tunnel paint booth consists of the following sections:

- plenum chamber;
- spray cabin up to grate level;
- air conditioning system.

The separation system for the paint overspray is located below the cabin grating.

In the walkable plenum chamber, the conditioned air from the HVAC systems is distributed evenly over the entire zone. The system is structured as follows:

- air distribution duct;
- filter plenum.

From the air distribution duct, the supply air passes through perforated plates into the filter plenum, which is separated from the cabin zone by the filter cover. The ceiling filters present in the filter cover are primarily used for uniform air distribution in this zone. In addition, the air is once again 'finely filtered' through the filter mats before entering the cabin, in order to prevent the penetration of dust and fibre particles into the airway.

##### Spray cabin

The spray cabin consists of self-supporting frame elements with planking. The inner side walls are equipped with windows to the control areas and are even to avoid deposition of paint on landings and in dead zones. Access from the control areas arranged on the long side is possible via doors with safety interlocks. The control areas can only be entered via airlocks.

The car bodies are mounted on transport skids and are automatically transported to the various painting stations. They are dedusted using different techniques [reference to BAT-CP, described elsewhere] before entering the painting zones. In a painting booth, 10 to 20 vehicles are machined simultaneously.

After completion of the coating process, the car bodies are transferred into a dryer.

### *Ventilation system*

The conditioning of the air to the required parameters is achieved using ventilators with heaters (direct or indirect heating), coolers, humidifiers, filters and fans. The air is supplied to the cabin via a plenum chamber over the whole cabin area. The exhaust air is withdrawn from the cabin via fans. The cabins are operated with a low vacuum to prevent leakage of solvents. The paint overspray deposition can be carried out with different systems (reference to BAT-CP, described elsewhere). During wet washout, the humidity increases to over 90 %. Therefore, use of circulating air is only possible with high energy expenditure for dehumidification.

In the case of the dry deposition of the lacquer dispersion, recirculating air operation is useful since the parameters of the air, in particular the humidity, are not significantly changed.

Heat recovery is possible and efficient in wet washing through heat wheels. In the case of dry deposition with recirculating air guidance, the solvents are concentrated. These are often treated in a thermal exhaust gas purification plant with heat recovery.

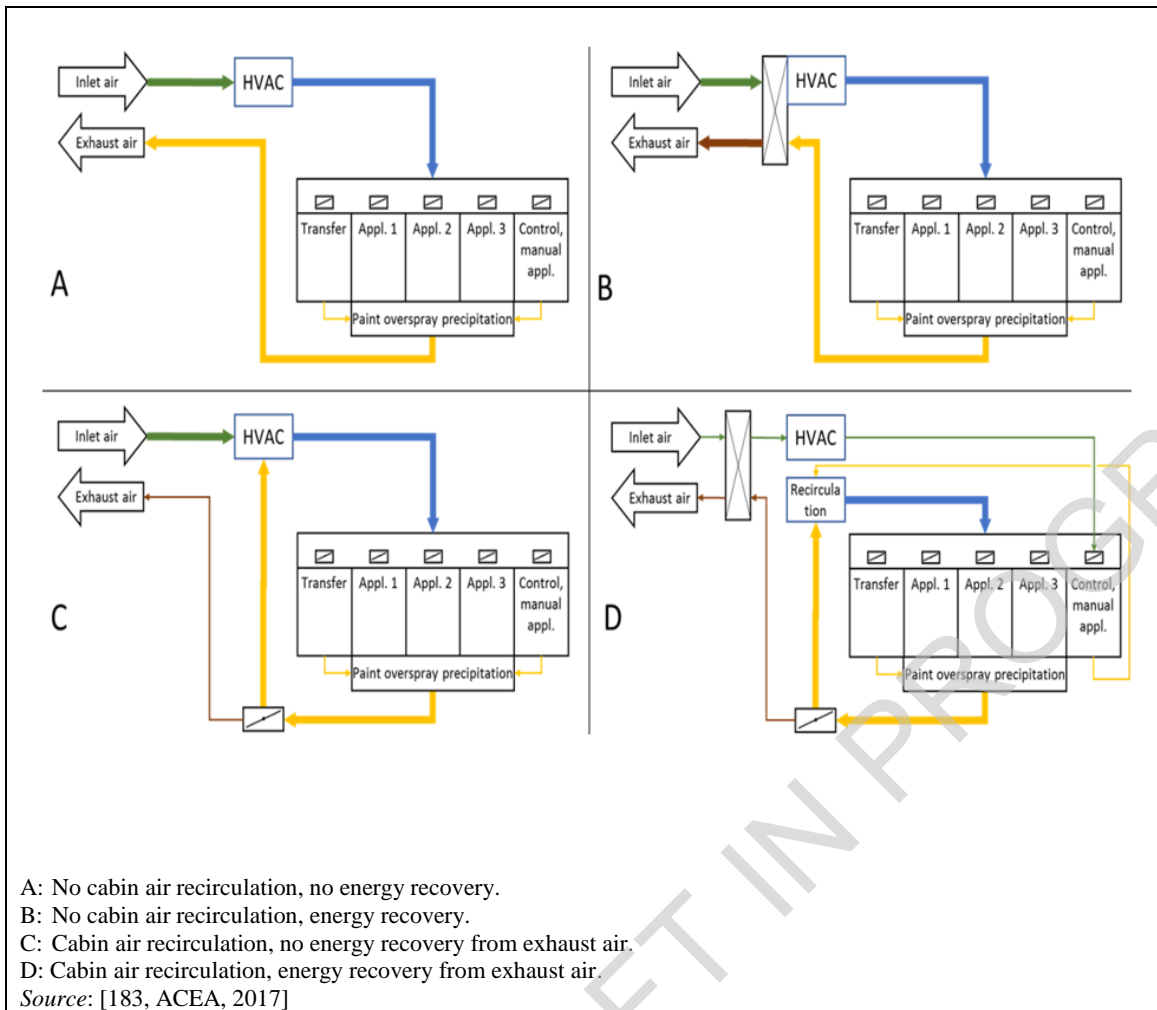
Various variants of air routing and energy recovery are shown in Figure 2.34 and Figure 2.35.



- 1 Inlet/outlet air heat exchanger.
- 2 Inlet air conditioning.
- 3 Plenum chamber and inlet air distribution.
- 4 Application zone with robots and body conveyance system.
- 5 Control room.
- 6 Paint overspray separation (example: cross venturi scrubber).
- 7 Reservoir for scrubber water circulation system.
- 8 Exhaust air ventilator.

Source: [183, ACEA, 2017]

Figure 2.35: Structure and air conduction of a spray booth



**Figure 2.36: Different variants of air routing and energy recovery**

Paint boxes

In contrast to large pass-through cabins with simultaneous coating of many bodies in different painting stations, in a paint box a single body is coated. This type is used for:

- small-scale passenger car production;
- truck chassis painting;
- bus painting;
- paint repair operations.

All necessary working steps for coating a vehicle are carried out successively at the same workstation. Paint overspray is collected in dust filters. For drying, either IR radiators are used, hot circulating air is introduced into the painting booth or the body is transferred into an adjacent single body dryer oven. (Dürr-Krouzilek 2011).



Source: [183, ACEA, 2017]

**Figure 2.37: Paint box for single vehicle painting**

#### Dip tanks

The pretreatment and electrocoating zones are also equipped with housings. These are kept under small negative pressure (1 mbar) to avoid fugitive emissions to the nearby workplaces.

#### **Achieved environmental benefit**

- Elimination of fugitive emissions.
- Reduction of solvent consumption and emission.

#### **Environmental performance and operational data**

Typical dimensions of a coating cabin (including flash-off zones, excluding attached control zones) are presented in Table 2.26.

**Table 2.26: Typical dimensions of a coating cabin including flash-off zones, excluding attached control zones**

Paint process	Capacity (unit/h)	Length (m)	Width (m)	Ventilation (m <sup>3</sup> /h)	Occupancy rate (unit/cabin)	Painting stations (bells, guns)
Primer						
Base coat						
Clear coat						
Electrocoat						
Paint box, (passenger cars, truck chassis, bus), new painting or paint repair						
<i>TWG please provide information</i>						

The requirements to be met in the air conditioning of spray booths are presented in Table 2.27.

Table 2.27: Requirements for air conditioning in pass-through paint booths

	Relative humidity (%)	Temperature (°C)	Downdraft velocity (m/s)
Solvent-based paint	40–85	20–30	0.3–0.5
Water-based paint	60–70	20–26	0.3–0.5
Water-based one-layer topcoat	55–75	20–26	0.3–0.5

**Cross-media effects**

High energy demand for air conditioning:

- When using wet washing, as a rule, a 100 % fresh air fraction is necessary since the very moist exhaust air can only be reused with high energy consumption for dehumidification.
- When dry deposition is used, a circulating air volume flow of up to 90 % is possible. However, the recirculation rate is limited by the fresh air demand of the control zone, by manual work stations, or by the need to not exceed 25 % of the lower explosion limit. Usually 75– 80 % recirculation rates are observed.

**Technical considerations relevant for applicability**

Pass-through paint booths are generally used in the paint shops for serial coating of passenger cars, vans and trucks. Enclosed cabins are standard in electrocoating and pretreatment.

**Economics**

*TWG please provide more information*

**Driving force for implementation**

- Product quality.
- Workplace health and safety.

**Example plants**

- Tunnel spray booths and housing for pretreatment and electrocoating are found in all high-volume vehicle paint shops.
- Single cabins (paint boxes) are standard for low-volume production (e.g. sports cars, truck and bus paint shops).

**Reference literature**

Dürr-Krouzilek, Ralf (2011): Ressourcen-Effizienz auf hohem Niveau. Reinigungs- und Lackierlinie für Nutzfahrzeuge. In: JOT 51 (3), S. 42–45. DOI: 10.1365/s35144-011-0042-5.  
 VDI 3455, 2013-08: Emissionsminderung - Anlagen zur Serienlackierung von Automobilkarosserien [169 VDI 2013]

**2.4.8.2 Rinsed electrofilter (overspray separator, E-Scrub)****Description**

System to separate overspray particles from the process air using electrostatic filters (see general description, Section 17.10.4.6).

**Technical description**

E-Scrub is an overspray separation system located below the grid level of the spray booth. The loaded air will be treated in electrostatic filters.

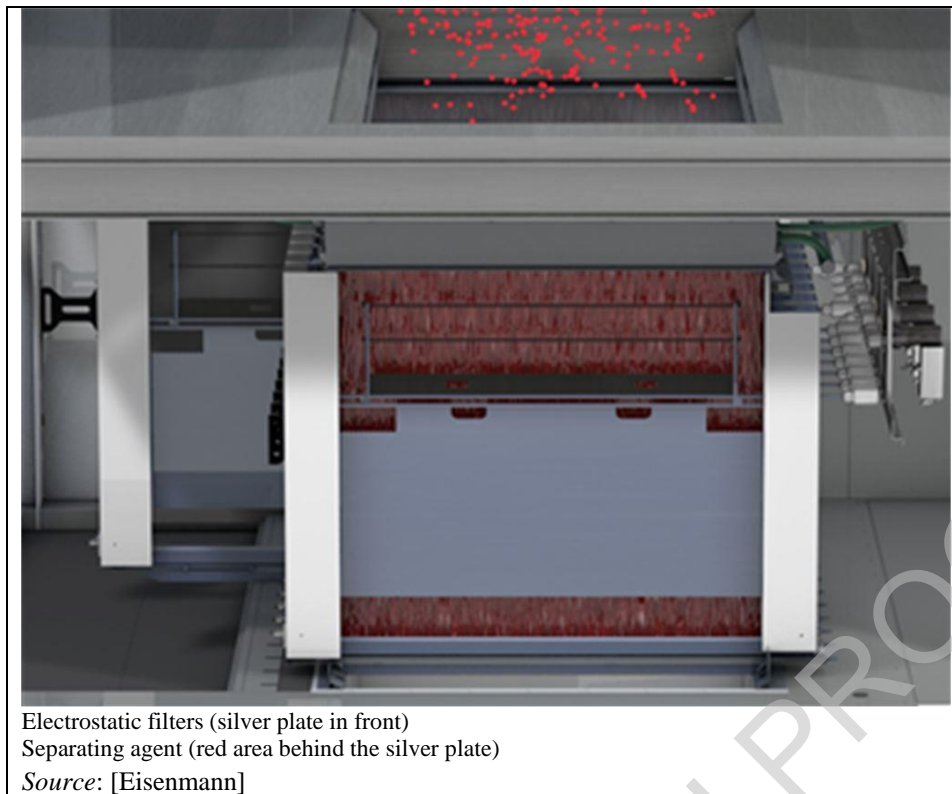
Exhaust air with overspray flows through the intake area to the separation module. As the air passes through the module overspray particles are removed. As the system achieves a very high degree of separation, the spray booth can be operated with recirculated air. A large proportion of the scrubbed air is sucked in by a recirculation fan and returned to the booth. Depending on the

exhaust air's solvent load, a portion of it is removed from circulation and replaced with fresh air. Separation modules comprise an alternating arrangement of active and passive elements. In the active elements, a corona cloud forms under a high voltage charging all paint particles. These particles are then attracted by the passive grounded separating plate. This is covered with a thin layer of separating agent by a coating system installed above it. The paint particles are bonded to the separating plate and detackified by the separating agent. The agent containing overspray flows into the collection tank below the E-Scrub system. From there it is returned to the coating system via the system tank. Part of the agent is scrubbed of overspray by a discharge system and returned to the separating agent cycle.



Source: [Eisenmann]

Figure 2.38: Rinsed electrofilter system



**Figure 2.39: Detail of electrostatic filters and application of separating agent**

**Achieved environmental benefits**

In a E-Scrub system the paint particles are separated > 99 %, with a remaining particle content of 0.3–0.8 mg/m<sup>3</sup>.

**Environmental performance and operational information**

The separating agent is circulated in the system. Only a small stream of separating agent will be removed and disposed of with the overspray.

The operation and maintenance areas of the electrostatic filter are separated. The contact between the electrostatic filter and the generators is automatically activated when the module is inserted or removed. The handling is done in the operation area.

The electrostatic filters and the separating agent supply will work largely in automatic mode. The system function will be monitored by the programmable logic controller (PLC).

**Cross-media effects**

No information provided

**Technical considerations relevant to applicability**

The E-Scrub system is suitable for systems of all sizes.

**Economics**

No information provided

**Driving force for implementation**

The particle content of the exhaust air is low enough that the air can be recirculated. This reduces the cost and energy consumption of conditioning the cabin air.

**Example plants**

Several paint shops in Europe, the US and China.



**Reference literature**

[ACEA, 2017]

**2.4.9 Water management and waste water treatment**

The following techniques are commonly applied:

- reverse cascade rinsing, see Section 17.4.1.3;
- use of ion exchanger, see Section 17.4.1.5 ;
- ultra and nanofiltration, see Section 17.11.8.

WORKING DRAFT IN PROGRESS

**[7 COATING OF VANS, TRUCKS, AND TRUCK CABS]**

*This section has been merged with Section 2*

**[7.1 General information on the coating of vans, trucks and truck cabs]**

*This section has been replaced by Section 2.1*

**[7.2 Applied processes and techniques in the coating of vans, trucks and truck cabs]**

*This section has been replaced by Section 2.2*

**[7.3 Current consumption and emission levels in the coating of vans, trucks and truck cabs]**

*This section has been replaced by Section 2.3*

**[7.4 Techniques to consider in the determination of BAT for the coating of vans, trucks and truck cabs]**

*This section has been replaced by Section 2.4*

*TWG please comment if any of this information is still necessary, e.g.it contains Technical considerations relevant to applicability not found elsewhere.*

In Chapter 16, techniques are discussed which might also be applicable to the coating of trucks and commercial vehicles. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to the coating of trucks and commercial vehicles. In Table 17.1, the general techniques relevant for the coating of trucks and commercial vehicles that are described in Chapter 16 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in

The EGTEI synopsis sheets for the coating of vans, trucks and truck cabs (see Annex 21.3.1) give some data on the cost benefit at a European level of some techniques to reduce VOC emissions. However, the EGTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as cross media effects or of the technical characteristics of individual installations or products [85, EGTEI, 2005] [86, EGTEI, 2005].

The paint process in the vehicle manufacturing industry is a highly complex and fully integrated operation consisting of many interdependent steps. As each step influences all others, decisions made about one step can impact on all or part of the process. Equally, some combinations of techniques may be incompatible with each other. Also, an existing application system may limit the choice of coatings. Therefore, when considering techniques for determining BAT, it is not meaningful to select each step separately.

<b>Technique</b>	<b>Section number</b>
Environmental management tools	17.1.1
Ongoing environmental improvement	17.1.2
Benchmarking	0
Storage and handling of solvents	17.2
Installation design, construction and operation	
Monitoring	17.3

Mass balances for solvents	17.3.1
Water management	17.4
Energy management	17.5
Raw material management	17.6
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Substitution: using less harmful substances	
Paint in paint spray booth	17.10
Water emulsion techniques	17.10.2
Cold plate spray booths	0
Condensation	17.10.6.1
{Adsorption	0
Waste water treatment	17.11
Waste minimisation and treatment	17.12
Dust abatement	0
Odour abatement	17.13
Noise abatement	0

**Table:** reference to techniques generally applicable to the sector

### Conventional solvent-based materials

**Description:** For the general description, see Section 0. Solvent based paint systems are applied on drivers cabs as:

- filler: 50 wt % solvents
- 1 coat topecoat: 45 wt % solvents
- base coat: 75 wt % solvents
- clear coat: 45 wt % solvents.

**Achieved environmental benefits:** No data submitted.

**Cross-media effects:** This type of coating system has an approximate range of VOC emissions before abatement of 193 to 233 VOC/m<sup>2</sup>.

**Operational data:** In metallic paints, the base coat and clear coat are always solvent based. The layer thickness of the base coats amounts to 10–20 µm, and that of the subsequently applied clear coat amounts to approx. 40 ± 5 µm. 1 coat topecoats are applied with a layer thickness of 30–40 µm.

For cabs, waste gas from the driers is usually connected to a post combustion unit, while the spray booth waste gas is not usually treated (only at one site).

However, after painting axles, the greatest portion of the applied solvent is emitted without being treated, since emission reduction measures are not applied, or the drier is connected to a post combustion unit.

**Applicability:** No data submitted.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** Volvo in Umea (Sweden), combines incineration with zeolite filtration for solvent recovery. The emissions are less than 1 kg per cab.

**Reference literature:** [13, DFIU and IFARE, 2002] [78, TWG, 2005] [133, May, et al., 2006]

## Replacement of solvent-based materials (substitution)

### Water-based paint systems

**Description:** For the general description, see Section 17.7.2.2. Water based paint systems are applied for:

- electrocoat: 8 wt % organic solvent
- filler/primer: 15 wt % organic solvent
- base coat: 15 wt % organic solvent.

The VOC emissions total for these coats is in the range 31 to 36 g VOC/m<sup>2</sup> without topcoat and prior to any abatement. About 25 different water based (2 component) topcoats are used for approx. 95 % of the chassis.

**Achieved environmental benefits:** No data submitted.

**Cross-media effects:** Since water based paints allow lower application efficiencies, an increased paint consumption has to be taken into account. It is reported that:

- the primer consumption for water based coatings is about 5 % higher than for conventional solvent based primers
- the base coat consumption for water based coatings is about 10 % higher than for conventional solvent based base coats.

**Operational data:** The DaimlerChrysler AG company in Kassel, Germany has been operating an installation that uses water based paints for the coating of axles since 1998. Due to these measures, 160000 litres of solvents are saved yearly.

**Applicability:** Replacement of solvent based primer and enamels involve changing the spray booths and the automatic spraying devices; this expense varies widely depending on the plant arrangement. In many cases, because additional space is needed to make the spray booths longer, a new plant has to be installed in a new building.

**Economics:** The cost of replacing one simple spray booth and related automatic spraying devices (i.e. a primer spray booth) varies from EUR 13 million to 25 million. The installation of a new plant in a new building varies, depending on the plant size, from EUR 60 million for a 25000 cabs/year plant to EUR 140 million for a 50000 vans/year plant.

**Driving force for implementation:** SED.

**Example plants:** Water based 1-coat topcoats are applied by MAN (Munich, Germany) and DaimlerChrysler AG (Kassel, Germany).

**Reference literature:** [13, DFIU and IFARE, 2002] [8, IFARE and CITEPA, 2002] [78, TWG, 2005] [133, May, et al., 2006]

## Paint application techniques and equipment

### Electrocoating

For a general description, see Section All electrocoatings (e-coat) used are water based; their content of organic solvents is typically 8 wt % and they are lead free. Truck chassis are

assembled from profiles that have already undergone the electrocoating dip process. At present, the immersion technique is widely used for the application of electrocoatings. Electrocoating implies high investment and material costs. [13, DFIU and IFARE, 2002]

### **High volume low pressure spraying (HVLP)**

For a general description, see Section 17.7.3.12. Primer is applied onto the interior and exterior surfaces of the driver's cab, via manually operated HVLP spray guns.

On truck chassis, water based material is applied using HVLP spray guns. The applied layer thickness varies from 40 to 60  $\mu\text{m}$ . Overspray is intercepted via a wet scrubber system with automated discharge of the paint sludge to the decanter. [13, DFIU and IFARE, 2002] [78, TWG, 2005]

### **Electrostatically atomising spray processes**

For a general description, see Section 17.7.3.9. 1 coat topcoat: 45 wt % organic solvents, with specific VOC emissions of 60–72 g VOC/m<sup>2</sup> that is applied by using electrostatic spraying.

Electrostatically assisted high rotation bells

For a general description, see Section 0. After the filler/primer is applied, a second layer is applied onto the outside surfaces via automated electrostatic spray applications via high rotation bells. The layer thickness varies from 25–35  $\mu\text{m}$ . A manual paint application is only carried out for special orders.

Solvent based base coat is usually applied by using an electrostatic spray application (50 %) and a regular spray application (50 %). Clear coat is applied by using electrostatic spraying.

In metallic paints, the base coat and clear coat are solvent based. The base coat is about 10–20  $\mu\text{m}$  thick, the subsequent clear coat 40  $\pm$  5  $\mu\text{m}$  thick and single layer topcoats are 30–40  $\mu\text{m}$  thick. [13, DFIU and IFARE, 2002]

### **Wet separation spray booths**

For a general description, see Section 17.10.4.1. These are commonly applied. [13, DFIU and IFARE, 2002]

### **Waste gas treatment**

#### **Oxidation**

For a general description, see Section 0. After rinsing at the end of the electrocoating process, the vans, trucks, cabs and chassis are dried in a drier that is usually equipped with an oxidiser.

Where solvent based paints are applied, drying over sand spray booths are usually equipped with an oxidiser. However, spray booths might be equipped with activated carbon adsorption combined with an oxidiser. [13, DFIU and IFARE, 2002] [8, IFARE and CITEPA, 2002]

The investment for the above emission reduction measures depends on the plant size.

For a truck cabs paint shop with a throughput of 25000 units/year, the investment for the installation of post combustion units on the dryers amounts to approximately EUR 3 million, which, per painted vehicle, corresponds approximately to EUR 12. In addition to this, energy costs of about EUR 300000/year are generated, which, per painted vehicle, is approx. EUR 12.

For a van paint shop with a throughput of 50000 units/year, the investment for the installation of post combustion units on the dryers amount to approximately EUR 4 million, which, per painted vehicle, corresponds to approximately EUR 8. In addition to this, an additional energy cost of about EUR 400000/year is generated, which, per painted vehicle, is approximately EUR 8.

{133, May, et al., 2006}

### **Adsorption to activated carbon**

For a general description, see Section 0. If solvent based paints are applied, waste gas from spray booths and driers can be pretreated, e.g. in an adsorption wheel followed by a post combustion unit.

For a truck cabs paint shop with a throughput of 25000 units/year, the investment for the installation of an adsorption regenerative device and a relative post combustion unit for partial treatment of the spray booths VOC emissions, amounts to approximately EUR 12 million, which, per painted vehicle, corresponds approximately to EUR 60. In addition to this, energy costs of about EUR 650000/year are generated, which, per painted vehicle, is approximately EUR 26.

For a vans paint shop with a throughput of 50000 units/year, the investment for the installation of post combustion units on the dryers amounts to approximately EUR 15 million, which, per painted vehicle, corresponds to approximately EUR 30. In addition to this, an additional energy cost of about EUR 1.2 million/year is generated, which, per painted vehicle, is approximately EUR 24.

{133, May, et al., 2006}

### **Water minimisation and waste water treatment**

The following techniques are commonly applied:

- ~~ultra and nanofiltration is commonly applied to the electrocoating dip baths, see Section 17.11.8~~
- ~~reverse cascade rinsing, see Section~~
- ~~use of ion exchanger, see Section 17.4.1.5~~
- ~~recycling of wet scrubber/ venturi scrubber water, see Section 0~~

**[8 — COATING OF BUSES —merged with cars]**

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005] [68, ACEA, 2005] [134, May, et al., 2006]

*This section has been merged with Section 2*

**[8.1 — General information on the coating of buses]**

*This section has been replaced by Section 2.1*

**[8.2 — Applied processes and techniques in the coating of buses]**

*This section has been replaced by Section 2.2*

**[8.3 — Current consumption and emission levels in the coating of buses]**

*This section has been replaced by Section 2.3*

**[8.4 — Techniques to consider in the determination of BAT for the coating of buses]**

*This section has been replaced by Section 2.4*

*TWG please comment if any of this information is still necessary, e.g.it contains Technical considerations relevant to applicability not found elsewhere.*

In Chapter 16, techniques are discussed which might also be applicable to the coating of buses. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to the coating of buses. In the general techniques relevant for the coating of buses that are described in Chapter 16 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in

The EGTEI synopsis sheet for the coating of buses (see Annex 21.3.1) gives some data on the cost-benefit at a European level of some techniques for the reduction of VOCs. However, the EGTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as cross-media effects or of the technical characteristics of individual installations and products [87, EGTEI, 2005].

The paint process in the vehicle manufacturing industry is a highly complex and fully integrated operation consisting of many interdependent steps. As each step influences all others, decisions made about one step can impact on all or part of the process. Equally, some combinations of techniques may be incompatible with each other. Also, an existing application system may limit the choice of coatings. Therefore, when considering techniques for determining BAT, it is not meaningful to select each step separately.

**Table: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management tools	17.1.1
Ongoing environmental improvement	17.1.2
Benchmarking	0
Storage and handling of solvents	17.2
Installation — design, — construction — and operation	
Monitoring	17.3
Mass balances for solvents	17.3.1

Water management	17.4
Energy management	17.5
Raw material management	17.6
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Substitution: using less harmful substances	
Waste gas treatment	17.10
Containment and collection of waste gases	17.10.2
Paint in paint spray booth	17.10.6.1
Water emulsion techniques	0
Cold plate spray booths	17.11
Waste minimisation and treatment	17.12
Dust abatement	0
Odour abatement	17.13
Noise abatement	0

### Conventional solvent-based materials

**Description:** Conventional solvent based paints have the following solvent contents by weight: 45 % for the primer, 45 % for the 1 coat topcoats, 75 % for base coats and 45 % for clear coats. The application is carried out manually with an application gun. Typically, the solvents in the waste gas from the dryers are reduced or destroyed (see Section 17.10), depending on the throughput of the installation and the emission levels.

**Achieved environmental benefits:** Compared to water based paint systems, direct energy requirements are lower due to the better climatisation and accelerated flash-off of solvent based systems. However, this does not include energy consumption for the abatement of solvents in waste gases.

**Cross-media effects:** In the plants described in Section the VOC emissions amount to approximately 225 g/m<sup>2</sup> without consideration of emission reduction measures for waste gases from the dryers

**Operational data:** Curing times are shorter than those required for water based systems, therefore, faster line speeds can be achieved in smaller areas due to reduced oven times. Solvent based systems can also operate over a wider temperature and humidity range. Stainless steel equipment is not required.

**Applicability:** Solvent based paints can be used in all phases of the painting operation (primer, solid topcoat, base coat, clear coat and repair), and can be used on metals and plastics. They may be applied to new and existing paint shops where space and cost are prohibitive for the use of alternatives and where material changes may not be technically possible.

**Economics:** No data submitted.

**Driving force for implementation:** Economic and technical restraints on existing paint shops and certain new paint shops make solvent based materials a preferred option for certain facilities. Increasing quality targets are also driving the use of solvent based materials.

**Example plants:** DaimlerChrysler Mannheim, DaimlerChrysler Neu Ulm both in Germany.

**Reference literature:** [13, DFIU and IFARE, 2002] [68, ACEA, 2004] [38, TWG, 2004] [134, May, et al., 2006]



## Replacement of solvent-based materials (substitution)

### Water-based paint systems

**Description:** For the general description, see Section 17.7.2.2. The following water-based paint systems are applied for the coating of buses:

- ~~electro coat: 3–4 wt %~~
- ~~primer: 8 wt % solvent content~~
- ~~base coat: 13 wt % solvent content.~~

**Achieved environmental benefits:** Significant reduction in VOC use and emissions can be achieved. By using electrocoat, the primer operation can be omitted, which leads to a solvent emission reduction of 90 to 130 g/m<sup>2</sup>.

**Cross-media effects:** Electrocoat containing lead should not be used, because of the dust emissions during grinding operations.

**Operational data:** No data submitted.

**Applicability:** With one exception, water-based paints are not applied as topcoats and in only one installation are city buses completely coated with water-based paints.

**Economics:** The electrocoat process is only economically feasible for installations with a very high throughput (>5000 buses).

**Driving force for implementation:** No data submitted.

**Example plants:** Daimler Chrysler, Mannheim, Germany; Iveco Italy.

**Reference literature:** [13, DFIU and IFARE, 2002] [134, May, et al., 2006]

### High solid paints

**Description:** For the general description, see Section 17.7.2.1. High solid-based paint is only applied in the 1-coat topcoat and has a solvent content of 40 wt %. The difference to the normal topcoats with 45 wt % solvent content is only marginal.

**Achieved environmental benefits:** No data submitted.

**Cross-media effects:** No data submitted.

**Operational data:** No data submitted.

**Applicability:** No data submitted.

**Economics:** No data submitted.

**Driving force for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002, 38, TWG, 2004] [134, May, et al., 2006]

## Paint application techniques and equipment

The spraying of buses is done manually, by using pneumatic and electrostatic spraying techniques. Electrostatic spraying is only use for primer. However, no further information was made available, on which of the following spraying techniques and equipment are applied:

- conventional high and low pressure spraying, see Section 0
- high volume low pressure spraying (HVLP), see Section 17.7.3.12
- electrostatically atomising spray processes, see Section 17.7.3.9
- electrostatically assisted high rotation bells, see Section 0
- electrostatically assisted compressed air, airless and air assisted spraying, see Section 17.7.3.14
- wet separation spray booth, see Section 17.10.4.1
- water emulsion techniques in spray booths, see Section .

### Electrocoating (e-coat)

**Description:** See Section All electrocoatings used are water based; their content of organic solvents is typically 3–4 wt %.

**Achieved environmental benefits:** Typically the specific VOC emission is in the range 6–7 gVOC/m<sup>2</sup>, depending on the surface of the body.

**Cross-media effects:** None.

**Operational data:** The advantages of electrocoating are consistent and complete coatings (also in cavities), no forming of edge runners, a high efficiency and the possibility for fully automated processes. Disadvantages are the essential high maintenance requirements of the paint tanks as well as for quality assurance.

**Applicability:** At present, electrocoating is widely used in coatings of cars, vans and trucks, but is only applied at a small number of bus assembly plants.

**Economics:** Electrocoating implies high investment cost and higher material costs.

**Driving force for implementation:** No data submitted.

**Example plants:** Daimler Chrysler Mannheim, Germany; Iveco, Italy.

**Reference literature:** [13, DFIU and IFARE, 2002] [134, May, et al., 2006]

### 3 COATING OF PLASTIC WORKPIECES AND METAL SURFACES NOT DESCRIBED IN OTHER SECTIONS

#### 3.1 General information

*This chapter is the result of the merging of the following chapters of the original STS BREF document (2007):*

- 9. Coating of trains
- 10. Coating of agricultural and construction equipment
- 13. Coating of other metal surfaces
- 16. Coating of plastic workpieces

In this chapter, the coating processes related to coating of plastic workpieces and miscellaneous metal products are discussed. These include the metal and plastic components of the following types of products as well as the products themselves: fabricated metal products, moulded plastic parts, small and large agricultural and construction equipment, commercial and industrial machinery and equipment, interior or exterior automotive parts, motor vehicle accessories, trains, bicycles and sporting goods, toys, etc.

A small number of installations submitted data and additional information [155, TWG, 2016] According to data submitted in the frame of the call for initial positions, the total number of installations in EU Member States is significantly higher [161, TWG, 2015]. The number of installations that participated in the data collection and the reported total number of installations are presented in

Table 3.1.

**Table 3.1: Total number of installations and number of installations that reported data for the coating of plastic workpieces and metal surfaces not described in other sections**

Activity	Reported number of installations at the submission of initial positions (2015) <sup>(1)</sup>	Number of installations submitted data <sup>(2)</sup>
Coating of plastic workpieces	36	7
Coating of metal surfaces not described in other sections	32	4
Coating of trains	2	0
Coating of agricultural and construction equipment	4	1
<i>Source: <sup>(1)</sup> [161, TWG, 2015], <sup>(2)</sup> [155, TWG, 2016]</i>		

The coating of plastic workpieces and other metal surfaces serve decorative, protective and functional purposes. Coating protects metal parts from corrosion by providing resistance to moisture, heat and other factors. Plastic parts may be coated to provide colour, texture or protection, improving appearance and durability, and can also function to attenuate electromagnetic interference / radio frequency interference signals, and to conceal mould lines and flaws in the substrate surface.

These coating processes for metal products and plastic parts may be divided into three main unit operations: (1) surface preparation, (2) coating application operations, and (3) cleaning activities. All three types of activities use VOC-containing compounds (i.e. coatings, thinners, and/or cleaning materials).

The three main process steps are briefly described below [160, USEPA, 2008].

### Surface preparation

Surface preparation is performed for two main reasons: to correct any flaws in the part prior to coating and to prepare the part to receive the coating. The amount of surface preparation a part requires or the types of surface preparation processes employed can vary greatly between metal and plastic part substrates.

Before a metal product can be coated, its surface must be thoroughly cleaned. The cleaning operation consists of the following basic processing steps: alkaline or acid cleaning, water rinse, phosphate treatment (typically iron phosphate), water rinse, and pretreatment and/or water rinse. The last step can involve drying the parts in an oven. In general, the cleaning chemicals used in this cleaning operation contain only a small amount of VOCs and therefore generate negligible emissions.

### Coating application

Surface coating is accomplished by applying a coating to the metal or plastic surface, followed by curing or drying the coating. The coating itself may be in the form of a liquid or powder. Several different types of application technology are used to apply liquid coatings, and the selection of the application technology can have a significant effect on the amount of coating used and the resulting VOC emissions from the operation. The most common types of liquid coating applicators include: air atomised spray coating, electrostatic spray coating, high-volume low-pressure (HVL) spray coating, dip coating, flow coating, roll coating, electrocoating, and autophoretic coating. Powder coatings can be applied through electrostatic spraying or dipping.

### Cleaning activities

Cleaning activities other than surface preparation also occur at metal or plastic surface coating installations. Cleaning materials are used to remove coating residue or dirt from coating equipment (e.g. spray guns, transfer lines), tanks, and the interior of spray booths. These cleaning materials are typically mixtures of VOC-containing solvents but low-solvent or solvent-free cleaning techniques and materials are available.

#### 3.1.1 General information on the coating metal surfaces not described in other sections

*[TWG please provide updated information]*

A wide range of metal surfaces are coated for corrosion prevention and/or decoration. They may be for finished products (such as cleaning machines) or in sub-assemblies that are a part of other products, such as engine blocks for vehicles. They are not dealt with individually in detail, but example data are given. Some examples are:

- steel furniture, e.g.:
  - furniture and fittings for commercial use, hospitals, etc.;
- household appliances, e.g.:
  - white goods: fridges, washing machines, etc.;
- mechanical engineering, components, cabinets:
  - e.g. for high-voltage switch gear;
- automotive sub-assemblies, e.g.:
  - engine blocks,
  - windscreen wiper assemblies,
  - radiators,
  - brake discs,
  - aluminium rims;
- construction, e.g.:
  - facade panels,

- door and window frames,
- heating panels, radiators.

This is a group of activities classed among 'other coatings' in the SED [73, COM, 1999]. The EGTEL data sheet for the industrial application of paints considers three sub-groups [92, EGTEL, 2005]:

- ~~general industry: trade coaters, general engineering, industrial equipment, original equipment, heavy engineering and ACE (see Chapter aerospace (see Chapter 5)~~
- ~~continuous processes: furniture, rigid metal packaging and drums (see parts of Chapter 10),~~
- ~~plastic coating: plastic and automotive OEM components (see Chapter **Error! Reference source not found.**).~~

### 3.1.2 General information on the coating of agricultural and construction equipment

*[TWG please provide updated information]*

The machinery produced in this industry are vehicles (e.g. tractors, earth movers.), or equipment used for specific purposes, which may or may not be mobile (e.g. screens or sieves). To cover the whole range of activities, the term agricultural and construction equipment is used here. Most companies manufacture their machines during the whole year while selling them mainly in spring. Due to the heavy seasonal fluctuations of the business, machines are placed outdoors with the impact of UV radiation, rain, marine atmosphere, sometimes for almost a year between manufacturing and vending, so gloss and colour retention, adhesion and corrosion protection are critical issues. However, the main task is corrosion prevention. In use, the coating has to sustain heavy mechanical and chemical stress. Chemical corrosion occurs due to aggressive liquids arising from the materials handled (e.g. potatoes, manure) and moisture. The life of the coating does not generally survive as long as the vehicle. Optical qualities of the surface are less critical than for cars.

Large enterprises are typically those manufacturing self-driving machines. Due to relatively high technological and optical demands, pretreatment and coating processes are quite sophisticated. Paint consumption is above 50 tonnes per year, associated with a solvent consumption of between 5 tonnes and 50 tonnes per year.

### 3.1.3 General information on the coating of plastic workpieces

*[TWG please provide updated information]*

A wide variety of modern products incorporate plastic parts, although many are used with the appropriate finish achieved in the moulding process, and do not require coating. In general, around 75 % of the paints supplied to this industry are applied to plastic parts of vehicles. This is predominantly for bumpers, wheel covers and steering wheels. The remaining 25 % of the paints are for coating televisions, hi-fis and computer housings.

The plastic parts coated for the vehicle industry include parts that are coated by the vehicle producer (in-line vehicle production or in separate coating lines), as well as parts that are coated by component suppliers. Plastic parts integrated in the car body often have to achieve a matching colour. Nowadays colour design is increasingly in the automotive sector, including the interior decoration, for example, colour matching the steering wheel to the instrument board or to the interior. In many cases, the car bodies and the components may be coated in different installations using different application devices and/or coating materials and good colour matching is of major importance.

Due to the increase in the use of recyclable plastics in the vehicle component supplier industry in recent years, the use of polyolefins has also greatly increased. These materials are non-polar and need a surface preparation to guarantee the necessary adhesion for the coating.

Plastics typically display certain basic characteristics, and these affect the type of surface preparation which can be applied, the type of coating which can be used, and the process used to apply it. Some basic characteristics of plastics are as follows:

- resistant to mechanical or thermal stress;
- chemically resistant;
- electrically non-conducting;
- additional wetting and adhesion properties compared to metal surface;
- possibility of leakage or migration of the plastic ingredients.

Coating systems need to be chosen carefully with respect to the solvent they contain, as some aggressive solvents may cause swellings and embrittlements, may create cracks in the plastic or reduce the adhesive strength of the coating system. Also, the coating needs to be more elastic than the substrate in order to resist deformations

### **3.1.4 General information on the coating of trains**

*[TWG please provide updated information]*

Besides high optical qualities of the paint, a good corrosion protection is also required for rail vehicles. The applied coating system must resist climatic impacts, aggressive cleaning agents (used for the removal of graffiti) as well as abrasion from sliding contacts. Locomotives that are operated by the German Deutsche Bahn AG are repainted every eight years.

## 3.2 Applied processes and techniques

### 3.2.1 Applied processes and techniques in the coating of metal surfaces not described in other sections

*[TWG please provide updated information]*

Any of the relevant techniques in Chapter 17 may be applied.  
The applied techniques reported in the data collection are:

Coating techniques:

- Spray application in enclosed coating cabin;
- Spray application in enclosed cabins with clean room condition;
- Airless spraying.

The applied paint supply systems are similar to those in vehicle coating e.g. paint container directly connected to robot/workplace, without pigging or flushing technique.

### 3.2.2 Applied processes and techniques in the coating of trains

*[TWG please provide updated information]*

The selection of the coating system, materials, colour and layer thickness is determined by the customer. Because of large volume flows and discontinuous operations, waste gas treatment is not used in small installations. However, in some large installations, the treatment of the waste gases from the dryers is common practice.

The coating processes of rail vehicles can be divided into the coating of new vehicles and maintenance operations. The coating systems are identical for both processes. Both activities usually take place where the rail vehicles are manufactured. The characteristics of the maintenance operations with environmental impacts are outlined in the following paragraphs and are also valid for new constructions:

- Repairation of the paintwork in the finishing department or during maintenance operations: The paintwork is partly sanded and renewed.
- Complete lacquer finish of old rail vehicles: As a function of the lacquer condition, the paint is sanded down to the ground coat or completely removed by blasting.
- Paint removal and new paint finish: After the reconstruction of rail vehicles, old paint is removed via blasting or sanded down to the ground coat layer. Then, a new coating is applied. In general, paint removal is done manually via grit blasting. For paint removal from aluminium and stainless steel (e.g. superstructures), corundum is used as the blasting shot. For normal steel, steel itself is utilised as the blasting agent. After blasting, the dust is removed from the surface by blowing with compressed air. Usually, all blasting materials are recycled.

The process of constructing and painting new rail vehicles is described in more detail in the following paragraphs. As the applied painting processes of construction and maintenance operations are identical, this is also valid for maintenance processes.

Table 3.2 shows the coating systems used for rail vehicle bodies according to the regulations of the Deutsche Bahn AG as an example for a possible layer construction.

Table 3.2: Layer construction for rail vehicles according to the regulations of the Deutsche Bahn AG

Area	Layer construction	Material <sup>(1)</sup>	Layer thickness of dried material (µm)
Complete rail vehicle body  Outside surfaces: Front and side wall including door and window housing, roof and also head areas made of glass fibre reinforced plastic	<b>Pretreatment</b>	<b>Blasting</b>	
	Ground coat	EP, WB	60
	Knifing filler	SB	60
	Primer	PUR or EP primer, WB	60
		PUR primer, SB (alternative)	40
	Topcoat	PUR, SB	40
		PUR, WB	20–30
		Base coat, WB	40
		PUR, SB and anti-graffiti paint, SB	40
			40
Roof	Primary coat	EP, WB	80
	Topcoat	EP, WB, thick film	140
Base frame, floor, underbody	Topcoat	EP, SB, thick film or one-component underbody protection (alternative)	140
			140–200
	Primary coat	EP, WB	60
Bogie frame	Primary coat	EP, WB	60
		EP, SB (alternative)	60
	Topcoat	EP, WB, thick layer	140
		EP, SB, thick layer (alternative)	140
	DIN component parts	Anti-corrosion wax	
Interior surfaces: Floor, roof, side and front wall	Primary coat	EP, WB	
	Topcoat	EP, WB, thick layer	
		EP, SB, thick layer (alternative)	
	Seam sealant	Sealing agent	
	Acoustic insulation	Artificial resins, WB	

<sup>(1)</sup> SB: solvent-based; WB: water-based; EP: epoxy; PUR: polyurethane.  
Source: [13, DFIU and IFARE, 2002]

### Pretreatment of the wagon bodies

Optional degreasing via aqueous-alkaline cleaning agents is carried out after assembly (especially for aluminium). Subsequently, the interior and the exterior surfaces are cleaned via blasting. The blasting agent is partially recycled.

### Ground coat application (onto exterior areas and interior surfaces)

Ground coat is applied onto the entire wagon. Paint application is carried out manually via an airless spray application. Besides conventional paints, water-based, two-component, chromate-free paints, based on epoxy resins are also available. The solvent content of these materials varies from 3–5 %. Approximately 60–100 µm are applied onto the roof and approximately 200 µm on the side walls. Component parts such as luggage racks are coated with solvent-based paints or powder coatings.

### Filling

After the ground coat is dried, a filler is manually applied via palette knives. The material has a solvent content of about 16 % (of which 8 % is reactive and not relevant for emission). After curing the material, sanding of the side walls takes place. Grinding dust is removed by blowing with compressed air and by using cleaning agents. Usually, the filler material is only applied onto welding seams (minimum filler application).

### Primer application (generally only onto exterior surfaces)



The primer is applied onto the side walls via an airmix spray application. As a primer, either a two-component, amine hardening, water-based epoxy material (containing 3 % of organic solvents) or a solvent-based polyurethane (containing 35 % of organic solvents) is used. The layer thickness amounts to about 60  $\mu\text{m}$ . The drying time is about two to three hours. If a dryer is used (80 °C), the drying takes about 45 minutes. The temperature of the substrate may not exceed 45 °C for completed wagons due to the electronic equipment.

#### **Topcoat application (generally only onto exterior surfaces)**

Depending upon the kind of the track, several layers of topcoat are applied. For the Deutsche Bahn AG, six different colours are used for city rail vehicles. Among these, three colours are utilised for coating the side walls, one for the roof, one for the underbody and one for the bogie frames. The lacquer is applied via airmix spray applications. In between the paint applications, evaporation takes place (one hour). After the last layer is applied, the paint is dried at temperatures of 50–60 °C. After two hours, the finished surfaces are masked and the next paint layer is applied. The layer thickness of the paint that is applied onto the side walls amounts to 40  $\mu\text{m}$ . It can be up to 120  $\mu\text{m}$  depending on the number of paint layers. About 120  $\mu\text{m}$  is applied onto the roof.

Predominantly, solvent-based topcoats and clear coats are processed. Customers do not often accept them. Good performance is needed from coating systems. This is important especially for high speed trains (300 km/h), for regular cleaning and removal of graffiti. Although water-based materials are already available, solvent-based topcoats are still preferred for the reasons mentioned earlier, and sometimes prescribed by specifications.

#### **Underbody protection**

The underbody is coated with a water-based underbody protection via an airless spray application. A minimum layer thickness of 120–200  $\mu\text{m}$  is applied.

### **3.2.3 Applied processes and techniques in the coating of agricultural and construction equipment**

*[TWG please provide updated information]*

Common issues for all kinds of coating of agricultural and other machinery are:

- complex and large three-dimensional objects;
- relatively thick metal sheets which are processed by laser-cutting, welding, etc.;
- necessity of pretreatment due to processing rough edges, residues, rust and oil on metal surfaces;
- multiple substrates (steel, cast metal, wood, thermoplastics, duroplastics, fibre-enforced plastics, pre-assembled parts);
- pneumatic, airmix and airless application, electrostatically assisted application, dipping, or/and electrocoating are possible;
- limited baking conditions due to mass or pre-assembled thermosensitive parts;
- one main solid topcoat colour (typical for the brand) and a few additional colours (design);
- single or dual layer system (primer plus topcoat on visible external surfaces, or single layer topcoat);
- high quality of finish with regard to corrosion protection (edges), gloss and colour retention, chemical resistance, adhesion, etc.

The typical process in central Europe for large self-driving machines (combine harvesters, potato seeders/harvesters) includes electrocoating (anodic single layer or cathodic primer) and topcoat application over primer (two-component high solids solvent-borne, sprayed on partial surface areas, or waterborne topcoat, applied by dipping). However, traditional technologies are still widely spread, especially for smaller machines.

Primers and single layer topcoats have to reach all parts of the machines. Due to the complex structure of objects, dipping of components before assembly is therefore the preferred process option, and can be automated. If installations are not available because low capacity cannot justify the investment, spray application is feasible with some drawbacks on quality issues. In order to reach the internal surfaces of machines, airmix application is preferred. For external surfaces, electrostatic support of the application is feasible and widely used.

### **Traditional technologies**

Primers: polyvinyl butyrate (PVB) based, or acid-hardened alkyd (phosphoric acid), for spray operations; or dipping with solvent-borne materials (organic solvents or chlorinated hydrocarbons, based on alkyd resins).

Single layer topcoat: dipping with solvent-borne materials is widely used; alkyd coatings contain organic solvents, even chlorinated hydrocarbons are still used.

Topcoat: traditionally solvent-borne polyester/alkyd.

### **New technologies**

Primer: two-component epoxy-based, solvent-borne or waterborne, for spraying; or waterborne coatings for conventional and electrocoating; resins are mainly polybutadiene (anodic electrocoat) or epoxy.

Single-layer topcoat: waterborne coatings are available for conventional and electrocoating; resins are mainly acrylic due to demands for UV stability.

Topcoats: isocyanate-hardened acrylate/polyester (medium solids, high solids, or waterborne), or one component acrylic (waterborne, high bake), for spraying; or polyester or acrylic coatings (waterborne) for conventional dipping. Powder coat has been used successfully.

Usually, there is only one colour primer and a maximum of four colours for liquid topcoats. So for epoxy primer as for isocyanate-hardened topcoats, two-component mixing machines are technically and economically feasible.

### **3.2.4 Applied processes and techniques in the coating of plastic workpieces**

*[TWG please provide updated information]*

Generally in the serial coating of plastic parts, three issues need to be addressed:

- surface preparation;
- structure of the coating;
- coating system and application technique applied.

#### **Surface preparation**

Surface pretreatment may be applied to prepare the surface for the coating, e.g. to increase the adhesive properties of the surface (especially for applications of water-based coating systems), to activate the surface, to increase the electrical conductivity of the surface (e.g. for use with electrostatically supported application devices) or to reduce faults in the surface, e.g. created by the leakage of ingredients. Typical pretreatments include chemical pretreatments in baths; flame treatment; plasma processes; the corona technique; and fluoridation, which offers the advantages of one layer coating and enabling the parts to be stored for longer periods before being supplied for a following coating process.

#### **Structure of the coating system**

Depending on specific requirements two, three or four layers of paint may be necessary. A ground coat may also first be applied depending on the composite. On the surface of especially

difficult surfaces such as polypropylene, an additional primer may be necessary. For soft PVC or PUR soft foam, an isolating or inhibiting ground coat is needed to avoid migration of the softener. In order to smooth surface roughness, an elastic filling is applied. The topcoating may be either one or two layers, and is also elastic.

#### **Coating system and application technique applied**

The choice of coating system and application technique depends on the end-product needs. In Germany, predominantly solvent-based one- and two-component systems based on PUR and one-component paints based on acryl melamine are used, although water-based systems, UV cross-linking systems and powder coatings are also used.

Typically high pressure air spraying is used for wet paints. Depending on the workpiece's geometry, the application efficiency is between 20 % and 40 %. The high-volume low-pressure (HVLP) paint application method is also common for some applications, with achievable application efficiency factors varying between 25 % and 50 %. There is an increasing use of robots, as they allow a more homogenous layer thickness to be achieved compared to manual painting.

Electrostatic application techniques are also available but up to now have only been used for multilayer superstructures. Here, an electrically conducting ground coat is first applied with conventional spray guns, often followed by a base coat, also applied with conventional guns. The application of the clear coat layer can then be carried out electrostatically (e.g. by high rotating bells). Application efficiency factors can be greatly increased by using electrostatic techniques, e.g. if high rotating bells are used, application efficiency factors of up to 85 % can be achieved. In some cases, a maximum level of only 50–65 % transfer efficiency can be obtained (e.g. in the case of the complex parts of some processes in the automotive industry, for example the low conductivity of substrates in the case of plastic parts). However, the electrostatic coating technique cannot be used for single layer coatings, as it needs an electrically conducting pre-coat.

In general, drying and curing are carried out at a maximum temperature of 80 °C, due to the heat sensitiveness of the substrate. However, in certain cases, heat-up zones of up to 135 °C and hold zones of up to 110 °C can be reached. For some plastics, UV and electron beam curing may cause a yellowing of pale colourings.

The following spray booths and techniques are applied:

- simple spray booth;
- spray booth and dryer;
- wet separation spray booth;
- dry-separation spray booth;
- water emulsion techniques in a spray booth;
- paint-in-paint spray booth.

#### **3.2.4.1 Coating of bumpers**

*[TWG please provide updated information]*

**An example of a simplified water-based bumper coating process is shown in Figure 3.1**

The workpieces being coated consist of polyurethane moulded pulps and thermoplastic plastics.

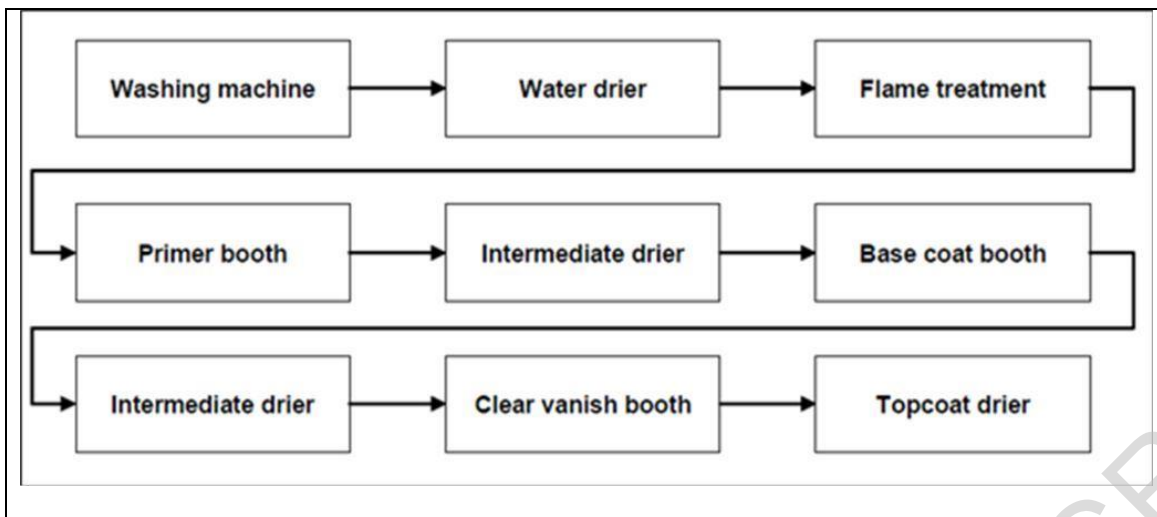


Figure 3.1: Water-based bumper coating process

### Surface preparation

Different techniques can be used for the surface preparation. Often spray cleaning with water is carried out by automation, with the parts progressively passing through different zones, e.g.:

- first degreasing with an aqueous-alkaline cleaning agent;
- rinsing with water;
- second degreasing with a watery, alkaline cleaning agent;
- rinsing with water;
- final rinsing with deionised water.

Spray cleaning with water and chemicals can be avoided for polypropylene bumpers by manually wiping the bumper with solvent impregnated wipes. In one example installation, the bumpers are cleaned manually with a water-isopropanol mixture (the proportion of isopropanol is 5 wt-%) and afterwards dried in convection dryers.

Cascade rinsing is usually used, in order to reduce water consumption. The water discharging from the parts can be used for substitution of evaporation losses of the degreasing step. Also the deionised water can be recycled. These measures allow an almost waste-water-free surface preparation (with the exception of the waste water produced by the periodic emptying of tanks for cleaning). After the cleaning process, the parts are transported through a blowing, drying and cooling unit. If a condensation dryer is used, the cooling unit is not necessary.

After drying, the workpiece's surfaces are typically activated by flame treatment or plasma ionisation. Polyurethane parts do not need any further preparation.

### Application of the coating

In general, bumpers are coated with a three layer coating consisting of a ground coat, a base coat and a clear coat. The paint is applied by robots or manually by using electrostatically assisted spraying or by spraying with HVLP guns. First, a primer is applied to the plastic parts. Primer can be either solvent-based (e.g. solvent-based two-component ground coating) or water-based. The primer may need to be dried (e.g. within a circulating airflow at 80 °C) prior to the application of subsequent layers. Application of the base coat is carried out with the same technique as the ground coat. Where the base coat uses medium solids paint, the solvent proportion can be up to 70 %. Base coats are one-component paint systems, either water-based or solvent-based. After the paint application, a conventional solvent-based two-component clear coat is applied and evaporated. Additionally, wet-on-wet application can also be used eliminating the need for intermediary drying zones.

After evaporation, the paint layers are dried in the dryer. Solvent-loaded exhaust air originating from the flashing-off areas and dryers are captured and passed to a thermal treatment unit. The achieved efficiency factor may be 95–99 % (depending on the load to the combustion unit). For example, a concentration of 277 mg C/m<sup>3</sup> in the raw exhaust gas is reduced to 25 mg C/m<sup>3</sup> in the cleaned gas. Cleaning of the overspray is carried out via wet deposition. Table 3.3 below shows the proportions of solvents in different coating systems.

**Table 3.3: Proportions of solvents in different coating systems used for the coating of bumpers**

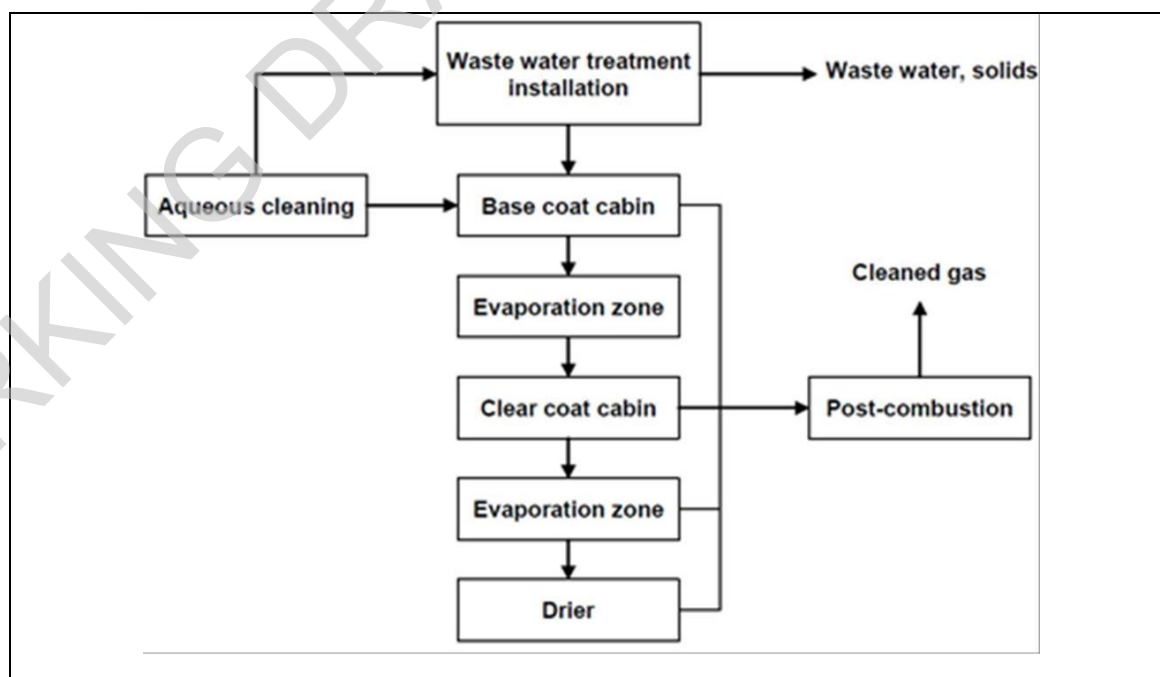
Coating structure and systems	Solvent proportion (wt-%)
Ground coat	
• solvent-based	40–55
• water-based	15
Base coat	
• solvent-based	50
• water-based	15
Clear coat	
• solvent-based	50
• water-based	30

#### 3.2.4.2 Coating of wheel covers

*[TWG please provide updated information]*

The coating system for wheel covers is characterised by two layers. First a conventional or water-based metallic base coat and subsequently a conventional solvent-based two-component clear coat or a UV clear coat are applied. The requirements for the coating include scratch resistance, water resistance and resistance against stone-chips, as well as a high surface quality. The coating is carried out by automation.

Figure 3.2 below illustrates the production procedure of wheel covers with solvent-based paints.



**Figure 3.2: Process flow for the coating of wheel covers with a conventional coating system**

Table 3.4 below compares some different systems in use.

Table 3.4: Comparison of the proportions of solvent in coating systems applied for the coating of wheel covers

Coating structure and systems	Solvent proportion (wt-%)
Base coat	
• solvent-based	75
• water-dilutable	10
Clear coat	
• solvent-based	50
• UV curing	10
• water-dilutable	16

### 3.2.4.3 Coating of steering wheels

For steering wheels, properties such as resistance against sun radiation, cleaning agents or sweat from hands have to be guaranteed by the coating. At present, steering wheels are typically coated by the in-mould technique. For this technique, a release agent is applied onto the heated mould and the in-mould coating is sprayed onto the release agent. In this way, the proportion of overspray and therefore the material loss is comparably low, approximately 20 %. After a short evaporation time, the mixed PUR components are poured in. During the foaming process within the closed mould, the material creates a strong connection with the coating. The applied coating has to be compatible with the mould release agent and to the polyurethane system used. Up to now, solvent-based one- and two-component coating systems have been in use.

### 3.2.4.4 Coating of reflectors

Reflectors require an extremely smooth and homogenous surface. The coating structure is a one layer type.

### 3.2.4.5 Coating in the production of televisions, hi-fis and computer housings

Nowadays, there is a trend in the audio and video sector for more colourful products and even individual customer requests regarding the colour design. The quality requirements for the coating of the housings include resistance against alcohols, skin fat, etc., scratch and abrasion resistance, and good optical surface properties. State-of-the-art is the serial use of water-based coatings, although solvent-based coating systems are still widely used. An application efficiency of 45 % can be achieved in the coating of television housings, with the coating being carried out by automation.

### 3.3 Current consumption and emissions levels in the coating of plastic workpieces and other metal surfaces not described in other sections

This group of activity emits NMVOC originating from the use of paints containing solvents, thinners and cleaning solvents. NMVOC emissions from this sector may vary significantly from country to country. At EU 25 level for 2000 (according to the RAINS model), NMVOC emissions were 543.8 kt representing 5.9% of total NMVOC emissions. Total activity was 1601 kt of paints used, giving an average emission factor of about 339.6 g NMVOC/kg paint consumed meaning that emissions from this sector are already partly treated in the EU 25 (unabated emission factors range between 690 and 750 g/kg of paint according to the sub-sector). [92, EGTEI, 2005]

Due to the wide range of this industry group, it is not possible to give details of consumptions and emissions. They will depend on:

- the type of processes applied
- end of pipe treatments applied
- products
- volume of production.

General information can be found with the appropriate techniques in Chapter 16.

The reported data refer to plants for the coating of metal surfaces not described in other sections (other metal surfaces - OMS), plastic workpieces (PW) and agricultural and construction equipment (ACE). No data were received from train coating plants.

#### 3.3.1 Consumption

##### 3.3.1.1 Material consumption

###### 3.3.1.1.1 Coating of trains

[13, DFIU and IFARE, 2002]

*TWG, please provide updated data*

In Table 3.5 the material consumption for specific paint layers is listed. The total solvent input (from thinners, cleaning agents and paints) of the inspected installation was 177.6 tonnes in 1999. Data for individual films of paint could not be determined.

Table 3.5: Material consumption per coated wagon

Paint/substrate	Consumption (kg)
Ground coat	200
Primer	35–40
Topcoat:	
Roofs	35
Windows	35
Braids, decor strips	5
Side wall underneath windows	15
Underbody protection	150–200
<i>Source: [13, DFIU and IFARE, 2002]</i>	

### Mass balances

No data submitted.

#### 3.3.1.1.2 Coating of plastic workpieces

[155, TWG, 2016]

Their consumption of raw materials in this sector depends on:

- the type of processes applied;
- product' specific substrate and geometry;
- volume of production.

Reported data from installations for the coating of plastic surfaces indicate a specific solvent consumption in the range of 0.15–1.02 kg solvent per m<sup>2</sup> of coated surface. The large deviation in this range is related to the differences in the product types and their geometries.

Only three installations reported detailed information on the process steps and the use of materials for the different coating layers.

Of these installations, two are using solvent-based (SB) material for the three coating layers (primer, base coat, clear coat) while the third is using both SB and water-based (WB) coats, WB for the base coat and SB for the clear coat.

~~Data for paint consumption in g/m<sup>2</sup> are difficult to obtain due to (i) the different geometries of the workpieces and (ii) this is not the usual way of expressing paint and solvent application in this industry. (It would have to be expressed as g/m<sup>2</sup> painted surface and not e coat surface as for vehicles, see Annex 21.6). It is more usual to express this as kg VOC/kg solids input (see Annex 0).~~

#### Coating of bumpers

For one example site in Germany (Volkswagen, Wolfsburg), in 2002 [119, May, 2006]:

- about 1 million bumpers were painted;
- surface area (external side only): between 0.9 m<sup>2</sup> and 1.5 m<sup>2</sup>;
- substrate: polypropylene with EPDM modification;
- three layer coating system with primer, base coat and clear coat;
- pneumatic atomisation of coating materials by spray-guns mounted on robots;
- drying oven after primer and clear coat, wet-on-wet process for base coat and clear coat.

Solvent consumption figures in Table 3.6 refer to a mixed coating system with solvent-based primer, water-based base coat and solvent-based clear coat. The solvent used may increase by



20 % when medium solid paint is used. If a complete solvent-borne system was applied, the solvent consumption would amount to 550 t/yr. Consumption of paint solids would be 207 t/yr. VOC emissions according to EVABAT range between 51.75 t/yr and 72.45 t/yr. Emissions are 0.25–0.35 kg VOCs/kg paint solids.

**Table 3.6: VOC use for bumpers coating (2000 data)**

Coating system	Solvent used * (t)	Total solvents used
Ground coat (solvent-based)	125	
Base coat (water-based)	31	
Clear coat (solvent-based)	84	
<b>Total solvent in paint</b>		240
Rinsing diluent ground coat	61	
Rinsing diluent base coat	9	
Rinsing diluent clear coat	41	
<b>Total rinsing diluent</b>		111
<b>Total solvent used</b>		351

NB: \* It has been reported that the solvent used may increase by 20 % when medium solid paint is used. If a complete solvent-borne system was applied, the solvent consumption would amount to 550 t/yr.  
*Source: [38, TWG, 2004]*

#### Coating of truck cab roof tops and other plastic parts for commercial vehicles

A jobbing coating shop in Germany reports the following data [119, May, 2006]:

- coating of about 30 000 truck cab roof tops and complete plastic part sets per year;
- surface area (external side only) between 6 m<sup>2</sup> and 11 m<sup>2</sup> per rooftop;
- substrate mostly fibre-reinforced SMC polyester.

The combination of techniques used is:

- predominantly two layer coating systems with primer surfacer and solid colour topcoat;
- atomisation of coating materials by high-rotation bells mounted on robots, assisted by shaping air, but without electrostatic charging;
- drying oven after topcoat, wet-on-wet process for solvent borne primer surfacer and topcoat.

In the case of the conventional medium solids system, solvent consumption was about 400 t/yr, and consumption of paint solids was (in 2005) 253 t/yr.

Due to specific technological requirements (i.e. covering of substrate defects, customer specification, wet-on-wet process), the jobcoater for plastic workpieces prefers to continue the use of solvent-borne coating materials. In the area of trucks and commercial vehicles, more than 95 % of objects are coated with single-layer topcoats instead of base coat/clear coat. The colour range is typically above 600, due to matching fleet colour schemes. This leads to a very high number of colour changes, including the purging of 5–7 m supply hoses for robots. As a consequence, large quantities of purging liquids are used (and recovered).

Table 3.7: Breakdown of conventional VOC materials

Paint	Consumption (kg/yr)	VOCs (%)	VOCs (kg/yr)	Non-volatiles (%)	Non-volatiles (kg/yr)
Putty	1 000	8.5	85	91.5	915
Sanding primer	3 900	29.5	1 150	70.5	2 750
Primer surfacer	88 000	32.4	28 512	67.6	59 488
Topcoat	133 000	42.2	56 126	57.8	76 874
Elastic additive	4 100	22.3	914	77.7	3 186
Base coat	5 050	77.3	3 904	22.7	1 146
Clear coat	10 400	54.0	5 616	46.0	4 784
Hardener	66 300	54.5	36 134	45.5	30 166
Diluent	28 600	100	28 600	0	0
Special products	275	46.3	127	53.7	148
Purge solvent	137 000	100	137 000	0	0
Structure topcoat	22 000	42.0	9 240	58.0	12 760
Powder	2 000	0	0	100	2 000
<b>Total</b>	<b>501 625</b>		<b>307 408</b>		<b>194 217</b>

The option to achieve low VOC emissions would be the introduction of high solids and very high solids coating material and adapted purging liquid (see Table 3.8). This would give an emission value of 0.29 kg VOCs/kg paint solids.

Low-emission materials include:

- very-high-solids wet-on-wet primer surfacer;
- high-solids topcoats;
- low-VOC purging liquid (70 % organic materials not classified as VOCs);
- additional low-emission products (see Table 3.8).

Table 3.8: Breakdown of low-VOC materials to achieve low VOC emissions

Coating material	Consumption (kg)	Solvent content (%)	Solvent content (kg)	Solid content (%)	Solid content (kg)
Putty	600	8.5	51	91.5	549
Wet-on-wet primer	98 985	15	15 343	84.5	83 642
Sanding primer	4 260	29.5	1 257	70.5	3 003
Primer surfacer	140	56.7	79	43.3	61
Topcoat	150 955	28.4	42 871	71.6	108 084
Hardener	49 507	25	12 376	75	37 130
Additive	624	22.3	139	77.7	485
Clear coat	11 027	37	4 080	63	6 947
Base coat	5 226	9.5	496	23.7	1 239
Diluent	27 618	100	27 618	0	0
Structured coat	17 022	8	27 618	54	9 192
Hardener	2 635	5	133	95	2 505
Special products	255	46.3	118	53.7	137
Purging liquid	106 311	30	31 893	0	0
<b>Total</b>	<b>475 165</b>		<b>137 815</b>		<b>252 974</b>
Recovery	197 185	33	65 071		
<b>Total VOC emission</b>			<b>72 744</b>		

### 3.3.1.1.3 Coating of metal surfaces not described in other sections (other metal surfaces – OMS)

[155, TWG, 2016]

Reported data from installations for the coating of other metal surfaces (OMS) indicate a specific solvent consumption range from 0.01 up to 0.5 kg solvent per m<sup>2</sup> of coated surface.

### 3.3.1.1.4 Coating of agricultural and construction equipment (ACE)

[155, TWG, 2016]

Data for only one installation was submitted. The main characteristics of the process stages are presented in Table 3.9.

**Table 3.9: Main characteristics of process stages for an ACE coating plant**

Stage	Pretreatment	Layer 1	Layer 2	Layer 3	Cavity preservation
Process	Cleaning, degreasing	Primer coating	Gloss	Lubricant and rust inhibitor	Cavity preservation
Material (VOC content)	Aqueous detergent emulsion	SB (305 g/l)	SB (425 g/l)	NI	Wax coat with solvents
Application method	High pressure spray cleaner, automatic	Spray application in enclosed cabins with clean room condition	Spray application in enclosed cabins with clean room condition	NI	NI
Paint supply	NI	Circulation lines fed from central mixing chamber, without pigging or flushing technique	Circulation lines fed from central mixing chamber, without pigging or flushing technique	NI	NI
Colour change, system purging	NI	Batch painting/colour grouping	NA	NI	NI
Dryer type	Convection drying	Convection drying	NA	NI	NI

Source: [155, TWG, 2016] #073

### 3.3.1.2 Energy consumption

Reported data show that the specific energy consumption values vary from 7 kWh/m<sup>2</sup> up to 35 kWh/m<sup>2</sup> of coated substrate surface. The specific energy consumption depends on the type of process, the substrate and specific aspects of the process. Given the significant share of energy consumed in waste gas thermal treatment in relation to the total energy consumption, it is worth noting that energetically efficient techniques have a major positive effect on energy consumption. As an example, at one reference installation, the replacement of thermal oxidation by a regenerative thermal oxidiser (RTO) resulted in a reduction of the total energy consumption of 66 % ([155, TWG 2016] # 080).

### 3.3.1.3 Water consumption

Reported values from installations for the coating of plastic workpieces show that the specific water consumption varies from 5 l/m<sup>2</sup> up to 30 l/m<sup>2</sup> of coated surface.

For the coating of agricultural and construction equipment the reported specific water consumption value was 0.26 m<sup>3</sup> per tonne of product

### 3.3.2 Emissions

[155, TWG, 2016]

#### 3.3.2.1 Total and fugitive VOC emissions

This industry group covers a wide range of activities with significant differences on:

- the type of applied processes;
- the applied end-of-pipe techniques;
- the products;
- the production volume.

The reported VOC emission values, expressed as percentage of the total solvent input, are presented in Figure 3.3.

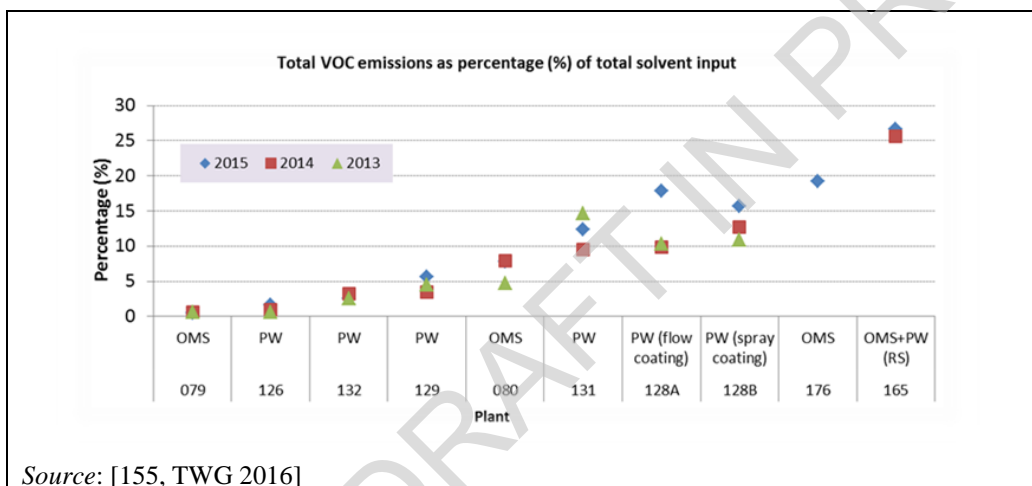


Figure 3.3: Total VOC emission values expressed as a percentage of the total solvent input

Contextual information related to the applied material and processes for the installations presented above is given in Table 3.10.

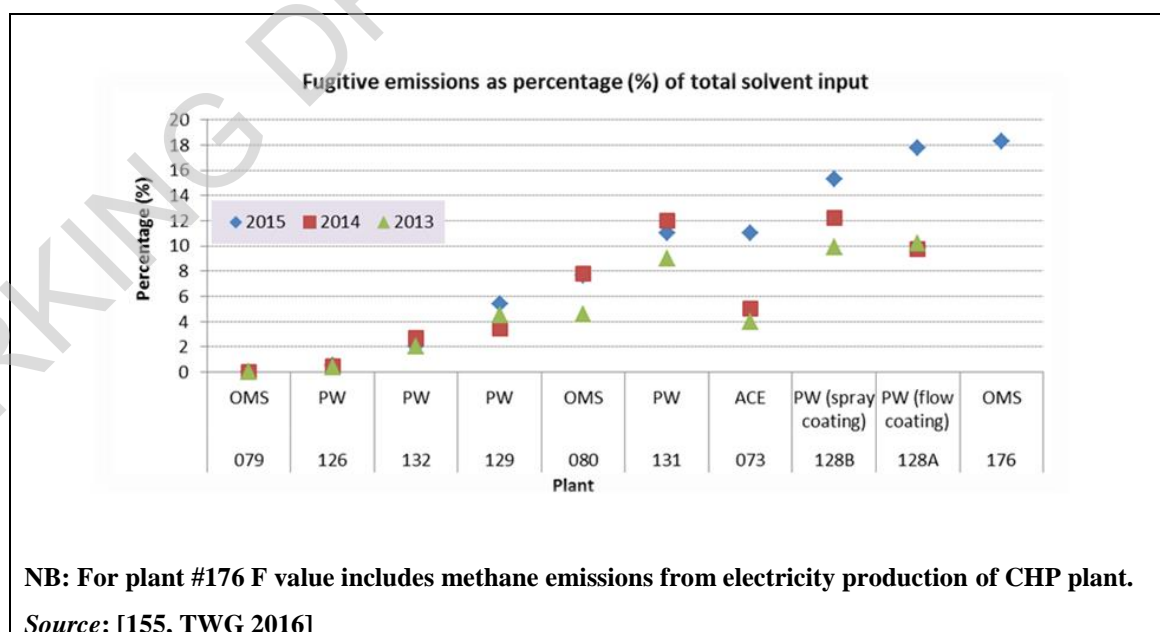
**Table 3.10: Information on applied coating materials and techniques at installations that reported emission data for the coating of plastic workpieces and metal surfaces**

Installation	Coating materials (VOC content)	Thinner/cleaning materials (VOC content)	Application and enclosure	Colour change
079	SB (33–73 %)	SB (100 %)	Spray application in enclosed coating cabin	Batch painting/ colour grouping
126	Primer: SB (80 %) Base coat: SB (75 %) Clear coat: SB (55 %)	Primer: SF Base coat: SF Clear coat: SF	Primer: HRB Base coat: HRB Clear coat: HRB	First-generation colour changers high paint loss
132	Primer: SB (80 %) Base coat: SB (75 %) Clear coat: SB (55 %)	Primer: SF Base coat: SF Clear coat: SF	Primer: HRB Base coat: HRB Clear coat: HRB	First-generation colour changers – high paint loss
129	Primer: SB -WB Base coat: WB Clear coat: SB	NI	NI	NI
080	SB (28 % solid content)	No thinner necessary	Airless application, paint container directly connected to robot, enclosed cabin	NI

NB:  
SB: Solvent-based.  
SF: Solvent-free.  
WB: Water-based.  
HRB: High-rotation bells.

The large variability of the reported values is characteristic of the wide range of activities covered in this industry group. In general, the reported total VOC emission values are below 15 % of the total solvent input.

The reported values of fugitive VOC emissions as a percentage of the total solvent input are presented in Figure 3.4.

**Figure 3.4: Fugitive VOC emission values expressed as a percentage of the total solvent input**

The comparison of the reported values for total and fugitive VOC emissions expressed as a percentage of the total solvent input shows the dominant role of fugitive emissions in the overall emissions pattern, with contributions that in most cases are of the order of 90 % to 99 %. That emphasises the necessity to control fugitive emissions.

The following have been identified as major sources of fugitive emissions:

- paint storage;
- paint preparation - mixing area (area where the mixing of the different paints and addition of additives and thinners take place), including the paint sampling which is usually done in the absence of the vacuum system;
- coating processes;
- drying processes.

The following main techniques have been identified for the minimisation of fugitive emissions:

- Handling and use of hazardous materials;
- Safe storage of hazardous substances and measures to prevent unplanned releases;
- Enclosed application zones with air extraction;
- Thermal post-combustion of extracted air;
- Air extraction from drying processes. The drying ovens are operated with negative pressure to avoid fugitive emissions. The extracted air is treated.

### 3.3.2.2 VOC emissions to air in waste gases

The reported values for periodic monitoring of VOC emissions in waste gases are presented in Figure 3.5.

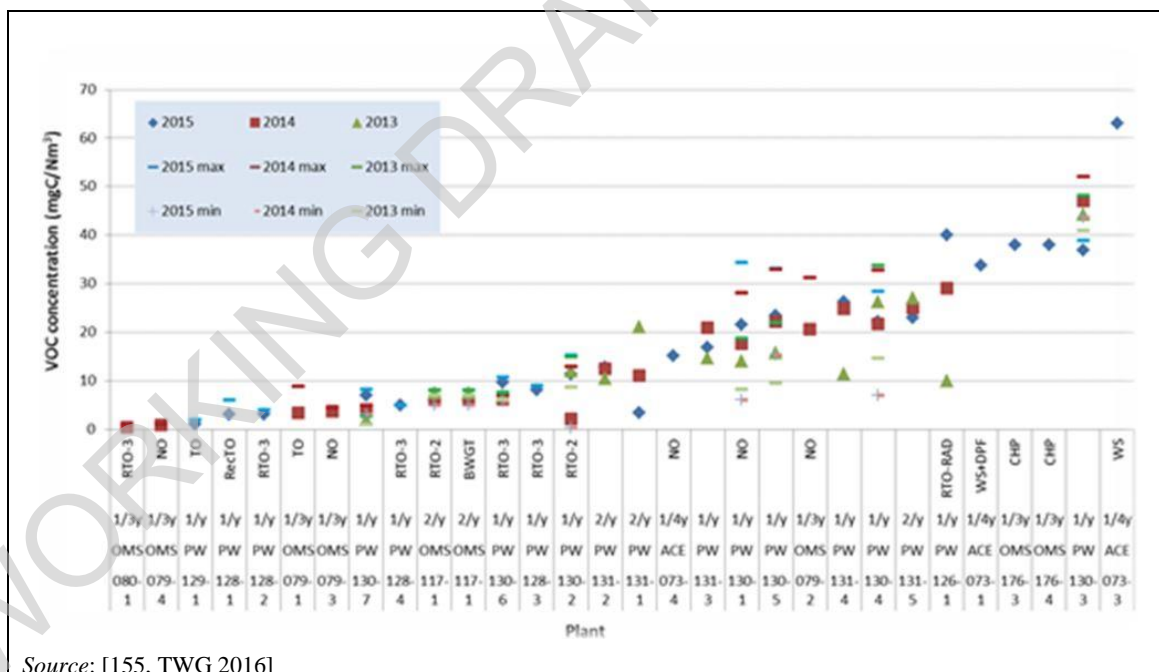


Figure 3.5: Reported values for periodic monitoring of VOC emissions in waste gases for the period 2013–2015

The basic statistical parameters of the submitted data for VOC emissions to air in waste gases from plants for the coating of plastic workpieces, other metal surfaces and ACE are presented in Table 3.11.

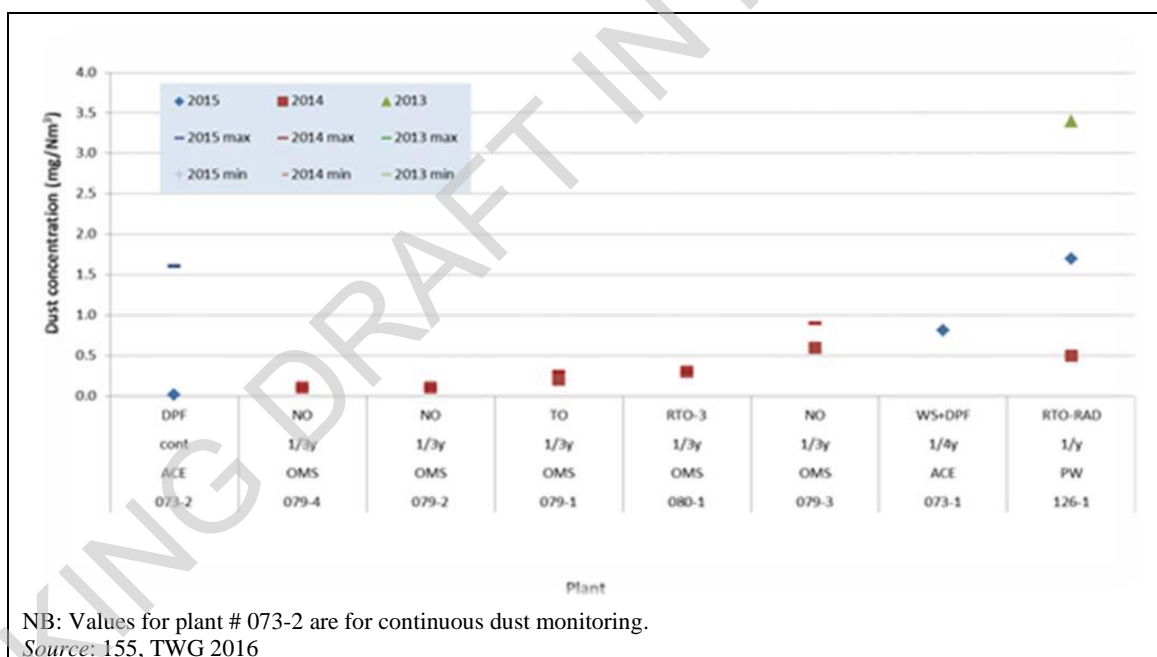
**Table 3.11: Statistical parameters of reported values for periodic monitoring of VOC emissions to air for the period 2013–2015**

Parameter	Year	2015	2014	2013
No of measurements		25	20	15
Average		19.0	14.3	15.4
Minimum		1.0	0.4	2.0
25 <sup>th</sup> percentile		6.0	3.9	8.8
Median		15.2	11.8	12.0
75 <sup>th</sup> percentile		26.3	21.8	18.5
Maximum		63.0	47.0	44.2

Source: 155, TWG 2016

### 3.3.2.3 Dust emissions in waste gases

The reported values for periodic monitoring of dust emissions in waste gases are shown in Figure 3.6.



**Figure 3.6: Reported values for periodic monitoring of dust emissions in waste gases for the period 2013–2015**

For the majority of reporting installations, dust abatement is not the top priority. Nevertheless, the use of dust abatement techniques (e.g. dry particle filter, wet scrubber) results in low dust emission values.

3.3.2.4 NO<sub>x</sub> and CO emissions in waste gases

**Nitrogen oxides**

Data for 12 monitoring points (from five plants) were reported for NO<sub>x</sub> emissions to air in waste gases with a yearly monitoring frequency in the most of the cases. All of the reported values are lower than 105 mg/Nm<sup>3</sup>.

The reported values for periodic monitoring of NO<sub>x</sub> emissions in waste gases are shown in Figure 3.7.



Source: [155, TWG 2016]

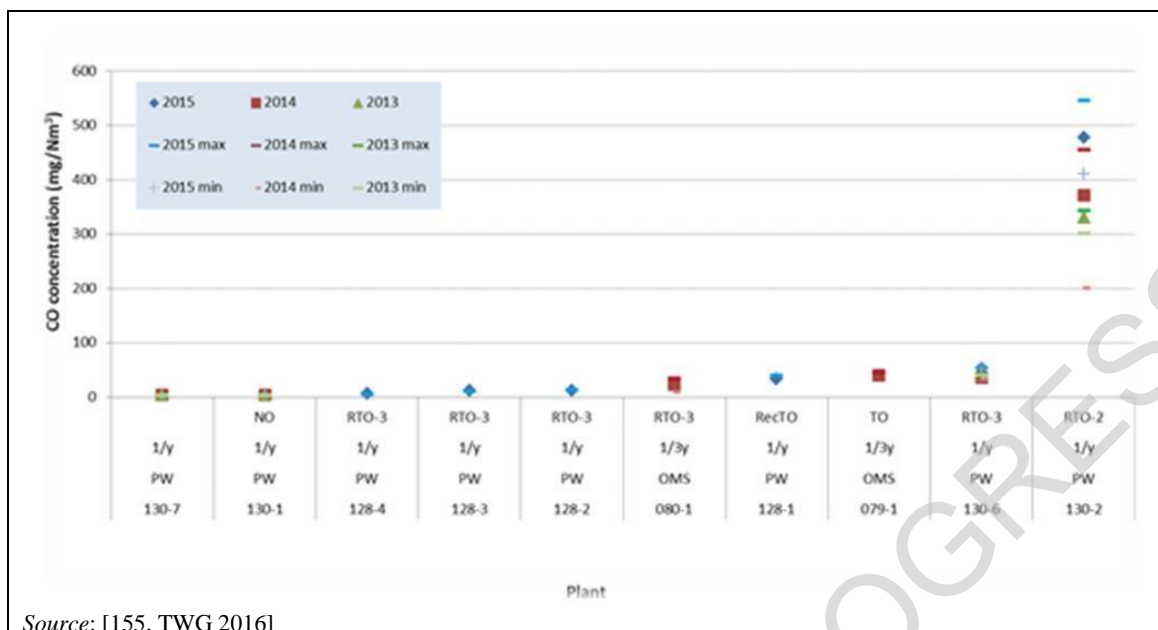
Figure 3.7: Reported values for periodic monitoring of NO<sub>x</sub> emissions in waste gases for the period 2013–2015

**Carbon monoxide**

Data for 10 monitoring points (from four plants) were reported for CO emissions to air in waste gases. The monitoring frequency varies between once a year and once every three years. All but one of the reported values are lower than 45 mg/Nm<sup>3</sup>.

The reported values for periodic monitoring of NO<sub>x</sub> emissions in waste gases are shown in Figure 3.8.





Source: [155, TWG 2016]

Figure 3.8: Reported values for periodic monitoring of CO emissions in waste gases for the period 2013–2015

### 3.3.2.5 Emissions to air from the coating of trains

[5, DFIU and IFARE, 2002] [38, TWG, 2004]

*[TWG please provide updated information]*

Only dust from overspray and blasting is deposited. Emission values of less than 3 mg/m<sup>3</sup> are achieved. VOC from coating processes are emitted to the air as direct or fugitive emissions. In some installations, which are subject to approval, thermal oxidation units are already used for treating the waste gases from the dryers. Emission values of less than 50 mg/m<sup>3</sup> are achieved.

However, as spray booths are extremely large and exhaust air volumes are around 200 000 m<sup>3</sup>/h, dry filtering systems are preferred.

If a standard, solvent-based paint system without waste gas cleaning is applied, about 326 g VOC/m<sup>2</sup> are emitted. From the total solvent input of 187.6 tonne into the inspected plant, 134.08 tonne were emitted and 53.52 tonne was disposed of as waste (a thermal combustion unit is not installed).

By the implementation of the following measures, emission values of <110 g VOC/m<sup>2</sup> are achieved:

- material specific techniques:
  - application of water-based ground coats, primers and topcoats
  - only for two-layer lacquer finishes, an application of a conventional clear coat
  - water-based primers and underbody protection in combination with thick layer materials
  - water-based primers and fillers
  - minimum use of knifing fillers and use low styrene content filler
  - processing of pre-coated (coil-coated) materials for new construction of rail vehicles
- process specific techniques:
  - reduction of painted surfaces, for example, by the use of adhesive foils for decorative designs or as graffiti protection
  - efficient application devices: HVLP, airless and air assisted airless spraying

- recycling of cleaning agents via distillation of solvent containing paint wastes and paint sludge
- use of automated supply of coagulant for wet precipitation for increased service life of the water.

### **3.3.2.6 Emissions to water from the coating of trains**

[5, DFIU and IFARE, 2002] [38, TWG, 2004]

*[TWG please provide updated information]*

Waste water is generated by the wet precipitation of overspray and the cleaning of application devices. More detailed data could not be determined.

### **3.3.2.7 Emissions to water from the coating of ACE**

[5, DFIU and IFARE, 2002] [78, TWG, 2005] [41, ISACOAT, 2004]

*[TWG please provide updated information]*

The rinsing tanks used for the pretreatment of workpieces generate waste water. In an installation, about 18 - 20 m<sup>3</sup> per day of waste water is generated. This amount can be halved by the implementation of the cascade technique. Due to the ultrafiltration unit, the dip coating installation does not generate waste water.

### **3.3.2.8 Waste generation**

[155, TWG 2016]

The following table summarises the reported data on the main types of waste generated in the coating of plastic workpieces (PW), metal surfaces not described in other sections (OMS) and agricultural and construction equipment (ACE).

**Table 3.12: Waste generation data**

Waste type	Source	Quantity range (t/yr)	Solvent content (%)	Destination
Paint sludge	Production processes	50–400	0-2	Delivered off site
Phosphate sludge	Production processes	NI		Delivered off site
Waste from coating removals	Production processes	3–4	2	Delivered off site
Water sludge	Waste water (pre)treatment	50–80	1-2	Delivered off site
Waste paint & varnish	Production processes	80–120	2	Delivered or sold off site
Waste solvents	Cleaning processes	50–170	5–95	Delivered off site
Sludge containing dust	Air emission abatement	35–80	1	Delivered off site
Used paint containers	Production processes	100–160	1	Delivered off site
Other contaminated packaging	Production processes	5–6	1	Delivered off site
Contaminated absorbents	Cleaning processes	1.5–3	2	Delivered off site
Solid waste from distiller	Distillation	1.5	38–75	Delivered off site
Liquid waste from distiller	Distillation	< 1	75	Delivered off site
Paint filters	Production processes	1–2	15	Delivered off site
Paint residues	Production processes	60–80	40–50	Delivered off site
<i>Source: [155, TWG, 2016]</i>				

The main identified techniques for the minimisation of waste generation are:

- reusable containers;
- distillation of used solvents;
- filter press for waste water sludge treatment and reduction of waste water volume;
- less colour changes in the process, resulting in lower solvent and cleaning material consumption.

#### **{Waste}**

Amongst other things, the following wastes are generated from the painting of rail vehicles:

- ~~paint sludge~~
- ~~air filters~~
- ~~cleaning agents~~
- ~~masking paper~~
- ~~waste paints~~
- ~~paint containers~~
- ~~blasting agents.~~

~~{Current consumption and emission levels in the coating of agricultural and construction equipment}~~

~~{Mass balances}~~

No data submitted.

~~{Consumptions}~~

~~{Materials}~~

No data submitted.

~~{Water}~~

No data submitted.

~~{Energy}~~

No data submitted.

~~{Emissions}~~

This industry is classed as 'other coatings' in the SED [73, COM, 1999](see Annex 0).

~~Emissions to air~~

~~Waste gas from painting booths and driers is treated by post-combustion; concentrations below 20 mg C/m<sup>3</sup> in the clean gas are achieved. Therefore, VOC emissions result primarily from diffuse sources, such as evaporation zones located in front of driers.~~

~~Waste~~

~~For a recycling of dip coat material from subsequent rinsing tanks, ultrafiltration can be used. The amount of waste paint containers can be reduced by the use of large returnable containers for standard topcoats.~~

~~{Current consumption and emission levels in the coating of plastic workpieces}~~

~~Due to the wide range of this chapter, it is not possible to give details of consumptions and emissions. They will depend on:~~

- ~~• the type of processes applied~~
- ~~• end-of-pipe treatments applied~~
- ~~• products~~
- ~~• volume of production.~~

~~This industry is classed as 'other coatings' in the SED [73, COM, 1999] (see Annex 0). General information can be found with the appropriate techniques in Chapter 16.~~

**[Mass balances]**

No data submitted.

**[Emissions]**

The coating of plastics is one of the activities grouped in the industrial application of paints (see Chapter 3). This group of activities emits NMVOC originating from the use of paints containing solvents, thinners and cleaning solvents. NMVOC emissions from this sector may vary significantly from country to country. At an EU 25 level for 2000 (according to the RAINS model) NMVOC emissions were 543.8 kt representing 5.9% of total NMVOC emissions. Total activity is 1601 kt of paints used, average emission factor is about 339.6 g NMVOC/kg paint consumed meaning that emissions from this sector are already partly treated in EU 25 (unabated emission factors range between 690 and 750 g/kg of paint according to the sub sector) [92, EGTEI, 2005].

**[Emissions to air]****Coating of bumpers**

Bumper paintshops are smaller than car paintshops, with correspondingly lower paint use.

Figure: shows the fate of the solvents in air emissions.

**Figure: Fate of the VOC input in the car bumper plant (2000, Volkswagen, Wolfsburg, Germany)**

**Coating of wheel covers**

The exhaust air from the spraying cabins, driers and evaporation zones is led to a post-combustion unit, and a cleaned gas concentration of 20 mg C/m<sup>3</sup> can be achieved. The cleaning process is carried out with aqueous alkaline cleaners.

**[Emissions to water]**

Paint particles are removed through wet scrubber systems. These systems are working in a closed loop, once to twice a year they are emptied and filled with fresh water. The waste water produced from the coating of bumpers is shown in

**[Waste]**

The wastes produced from the coating of bumpers are shown in

## 3.4 Techniques to consider in the determination of BAT

### 3.4.1 Coating of metal surfaces not described in other sections

In Chapter 17, techniques are discussed which might also be applicable to the serial painting of other metal surfaces. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to serial painting of other metal surfaces. In Table 3.13, the general techniques relevant for the serial painting of other metal surfaces that are described in Chapter 17 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

The EGTEI synopsis sheet for the industrial application of paints (see Annex 21.3.1) gives some data on the cost-benefit at a European level of some techniques to reduce VOC emissions. However, the EGTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as cross-media effects or of the technical characteristics of individual installations or products [92, EGTEI, 2005].

**Table 3.13: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

#### **New multiple coating systems for the painting of aluminium rims/wheels**

*Too site-specific –, not technique*

**Description:** A new production site for aluminium wheels achieves the following:

- replacement of chromium (VI) by a heavy metal free system in the pretreatment
- replacement of the solvent based paint by powder coating (acrylic resin)
- replacement of the solvent based metallic paint by water based metallic paint to reduce VOC emissions.

Simultaneously, the selected process meets high technical standards as well as quality standards of the customers and it should be economically optimised.

**Achieved environmental benefits:** The technique has the following benefits (see

- the use of chromium (VI) has ceased
- the application of water based paint for the metallic basis layer through a combination of high rotation bells and HVLP application lead to an efficiency degree of 80 %

- the powder coating for the base layer reached an application efficiency of 98 %
- for the final layer with acrylic-based powder coating, an application efficiency of 98 % has been reached
- the VOC emissions have been reduced by approx. 94 %.

**Cross-media effects:** No data submitted.

**Operational data:** See Table and.

		Conventional process		New process	
		Paint consumption	Solid application	Paint consumption	Solid application
<b>Coating/basic layer</b>	Basic powder	80 – 100 g		80 – 100 g	
	Application efficiency	98 %		98 %	
<b>Metallic basis layer</b>	Solvent-based wet paint	<60 g	12.5 g (approx.)	–	–
	Water-based wet paint	–	–	35 gram	<10 gram
	Application efficiency	50 – 60 %		80 %	
<b>Coating clear coat</b>	Solvent-based clear coat	<60 g	15 g	–	–
	Powder	–	–	45 g	
	Application efficiency	50 – 60 %		98 %	

Table: Input/consumption of resources per coated aluminium wheel

	Conventional process	New process	Remarks
<b>Coating/basic layer</b>			
Waste powder	<2.5 t/yr	<2.5 t/yr	No production chain, because the same process step is used
<b>Metallic-basis layer</b>			
VOC	37 t/yr (approx.)	4 t/yr (approx.)	Reduction by water-based coat about 90 %
Solid output in waste water	8 t/yr (approx.)	2 t/yr (approx.)	Reduction and replacement of hazardous substances, Cr (VI)
<b>Coating clear coat</b>			
VOC	29 t/yr (approx.)	0 t/yr	Reduction about 100 %
Solid output in waste water	20 t/yr (approx.)	–	Reduction about 100 %
Waste powder		1 t/yr (approx.)	New waste

Table: Emissions related to 1 million wheels/year

**Applicability:** Applicable in new installations.

**Economics:** Capital investment for the new installation: EUR 3.975 million. The process works economically, in particular because of the high level of automation and the controlled, minimised layer thickness.

**Picture deleted**

**Figure: Comparison of the use of solvent-based clear coat and the use of powder clear coat**

**Driving forces for implementation:** Solvent Emissions Directive 1999/13/EG.

**Example plants:** BBS Kraftfahrzeugtechnik AG, Germany.

**Reference literature:** [105, UBA—DE, 2002]

### 3.4.2 Coating of plastic workpieces

[13, DFIU and IFARE, 2002] [38, TWG, 2004, 119, May, 2006]

In Chapter 17, techniques are discussed which might also be generally applicable to the serial painting of plastic workpieces. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to serial painting of plastic workpieces. In Table 3.14, the general techniques relevant for the serial painting of plastic workpieces that are described in Chapter 17 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

**Table 3.14: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

The EGTEI synopsis sheet for the industrial application of paints (see Annex 21.3.1) gives some data on the cost-benefit at a European level of some techniques to reduce VOC emissions. However, the EGTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as cross-media effects or of the technical characteristics of individual installations or products [92, EGTEI, 2005].

#### 3.4.2.1 Minimisation of raw material consumption

##### Description

Some techniques to reduce the amount of waste in the painting process are:

- the optimisation of the painting process, including automation (see Section 17.6.3);
- dewatering of paint sludge;
- recycling paint sludge or the water emulsion.



**Achieved environmental benefits**

Reduction of the amount of waste (e.g. paint overspray) produced by the process.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

Coating of bumpers.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

Volkswagen, Wolfsburg, Germany.

**Reference literature**

[56, ACEA, 2005]

**3.4.2.2 Batch painting/colour grouping**

For a general description, see Section 17.6.3.1. This technique is commonly applied in the coating of bumpers.

Colour block building can reduce the consumption of coating material and rinsing diluents. Furthermore, the rinsing thinner can be captured and reused. About 66 tonnes of rinsing diluent can thus be saved per year, for a recapture proportion of 90 %.

[13, DFIU and IFARE, 2002]

**3.4.2.3 Pig-clearing systems**

For a general description, see Section 17.2.4.4. This technique is commonly applied in automated systems.

[13, DFIU and IFARE, 2002]

**3.4.2.4 Increase of the number of high-rotation bells****Description**

For a further increase of the application efficiency for water-dilutable primers and base coats, an increasing number of high rotation bells are in use for automated application techniques. Scrapper-cleanable ring circuits are used in installations with automated application techniques in order to minimise paint leftovers and rinsing losses.

**Achieved environmental benefits**

Decrease in the amount of waste generated.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

For base coats, water-based coatings are already applied. Applied to the coating of bumpers.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002]

**3.4.2.5 Water management**

**Description**

See Section 17.4. Some techniques to consider are the minimisation of dumping of the tanks from the spray booths to reduce water consumption and effluent discharges by minimising the building up of the paint sludge. Optimising the paint transfer efficiency also reduces the need to change the water. The waste water can be treated in a waste water treatment plant.

**Achieved environmental benefits**

The above techniques can achieve the emission levels shown in Table 3.15.

**Table 3.15: Waste water emission levels from the coating of plastic workpieces**

Waste water parameter	Concentration (mg/l)
Suspended solids	< 1 000
BOD	< 100
COD	< 2 500

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

Coating of bumpers.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[56, ACEA, 2005]

**[Conventional solvent-based materials]**

*Conventional techniques have been deleted if they can no longer be considered BAT.*

*This does not prohibit their use or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumption or emissions.*

~~Description: See Section 0. Solvent based coating systems are applied to ground coat, and base coat, although it is usually applied for the clear coat.~~

~~**Achieved environmental benefits:** Compared to water based systems, less energy is required for drying.~~

~~**Cross-media effects:** Solvent based materials generate VOC during drying that, in many cases, needs to be abated.~~

~~**Operational data:** Solvent based paints have a shorter drying time and, thus, a higher production capacity can be achieved.~~

~~**Applicability:** Steering wheels are currently coated exclusively with solvent based 1 and 2 component coating systems with the so called 'in-mould' technique.~~

~~**Economics:** No data submitted.~~

~~**Driving forces for implementation:** Short drying times are an important issue in the use of solvent technology. VOC abatement is typically required to satisfy national legislative requirements.~~

~~**Example plants:** No data submitted.~~

~~**Reference literature:** [13, DFIU and IFARE, 2002], [38, TWG, 2004]~~

**3.4.2.6 Replacement of solvent-based materials (substitution)****3.4.2.6.1 Water-based paints****Description**

For the general description, see Section 17.7.2.2. Water-based coating systems can be applied in ground coat, base coat and sometimes to the clear coat. The following water-based paint systems are commonly applied:

- one-component acrylate dispersion: 5 wt-% organic solvent;
- two-component PUR system: 10–15 wt-% organic solvent;
- two-component epoxy resin: 5 wt-% organic solvent.

**Achieved environmental benefits**

The amount of used solvents can be reduced by up to 48 % by the use of water-based ground coats, and consequently solvent emissions can also be reduced accordingly in the case of coating of bumpers.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

In the vehicle component supplier industry, water-based paints are already in use as fillers and base coats on, for example, bumpers and wheel covers. Waterborne paints can lead to mechanical constraints on the physical characteristics of the plastic. In the painting of television, hi-fi and computer housings, the serial use of water-based coatings is commonly applied. For

steering wheels, water-based in-mould coating systems are currently in the testing phase. First results indicate that slightly longer drying times will be necessary in comparison to conventional systems and therefore integration into existing processes should be possible.

The remaining issue is the introduction of a waterborne clear coat (50 % solid content, 13 % organic solvent content). Products are formulated and tested, but not yet approved and commercialised. This might lead to, ~~for example, in the reference plant in Section 0,~~ another 50 t/yr reduction of VOC emissions. First approvals may be expected in 2007.

### **Economics**

No data submitted.

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

### **Reference literature**

[13, DFIU and IFARE, 2002], [38, TWG, 2004, 119, May, 2006]

#### **3.4.2.6.2 Powder coating – conventionally dried**

##### **Description**

See Section 17.7.2.8. Powder coatings with conventional convection drying are currently not broadly applied due to the lack of electrical conductivity and the temperature sensitivity of plastics. Only small batches in the coating of small parts, such as composite parts of metal and plastics for car radiators.

##### **Achieved environmental benefits**

No data submitted.

##### **Cross-media effects**

No data submitted.

##### **Operational data**

Developments of thermal curing low temperature powder coatings look promising.

##### **Applicability**

No data submitted.

##### **Economics**

No data submitted.

##### **Driving force for implementation**

No data submitted.

##### **Example plants**

No data submitted.

##### **Reference literature**

[13, DFIU and IFARE, 2002]

#### **3.4.2.6.3 Radiation curing paints**

##### **Description**

See Section 17.7.2.4. UV curing coatings are applied to clear coats, e.g. on wheel covers, and contain 10 wt-% organic solvent. A progressive technique is the automated application of UV during coating on reflectors; the coating system contains about 5-10 wt-% organic solvent. Another relatively new industrial application of UV curing powder is for the coating of PVC floor tiles.

**Achieved environmental benefits**

Water-based and solvent-free radiation curing paints do not generate VOC emissions.

**Cross-media effects**

None.

**Operational data**

UV curing paints can be applied by several different techniques, such as brushing, rolling, casting, spraying and vacuum coating.

**Applicability**

These paints can be applied for all paint layers.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002]

**3.4.2.6.4 One-layer coating after fluoridation****Description**

If pretreatment of the plastic surface is done by using the fluor preparation, the filling layer is partially not necessary because this technique already creates a homogenous surface independent of the geometry of the workpiece.

Another advantage of fluoridation is that the fluoridated parts can be stored for a long time before being supplied subsequently for a following painting process.

**Achieved environmental benefits**

Reduction in VOC emissions and in coating materials.

**Cross-media effects**

None.

**Operational data**

No data submitted.

**Applicability**

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002]

**3.4.2.7 Paint application and curing techniques and equipment**

**In-mould painting**

**Description:** This technique is applied to steering wheels which are made from 2 component PUR materials that are poured into a mould. The production and painting of the wheel is done at the same time. For the coating of the wheel, a release agent is applied onto the heated mould and the coating material is sprayed onto the release agent. After a short evaporation time, the PUR material for the wheel is poured into the mould and the mould is closed. The foaming process of the PUR starts and at the same time that the coating material adheres to the PUR.

Until now only solvent based coating materials have been applied; water based in mould coating systems are currently in a testing phase.

**Achieved environmental benefits:** The proportion of overspray and, therefore the material loss is about 20 % of the input.

**Cross-media effects:** No data submitted.

**Operational data:** No data submitted.

**Applicability:** No data submitted.

**Economics:** No data submitted.

**Driving force for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002]

**[Conventional high and low pressure spraying]**

**Description:** See Section 0. Typically, pressure air spraying with the high pressure method is used for the processing of wet paints.

**Achieved environmental benefits:** Depending on the geometry of the workpiece, the paint application efficiency factor can vary between 20 and 40 %.

**Cross-media effects:** No data submitted.

**Operational data:** No data submitted.

**Applicability:** No data submitted.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002]

**High volume low pressure spraying (HVLP)**

*Repeats Section 17.7.3.12.*

**Electrostatically assisted high rotation bells**

*Repeats Section 17.7.3.13*

**Electrostatically assisted compressed air, airless and air assisted spraying**

*Repeats Section 17.7.3.14.*

**Processing of powder coatings – electrostatically assisted spraying**

*Repeats Section.17.7.3.14*

**Drying**

**Convection drying**

*Proposed for deletion*

**3.4.2.7.1 Ultraviolet (UV) curing**

*Repeats information in Section 17.8.5.2*

**Description**

See Section 17.8.5.2. In general, drying and curing are carried out at a maximum temperature of 80 °C due to the heat sensitivity of the substrate. One technique used is the automated application of UV curing coating systems (with a solvent proportion of about 5–10 wt-%).

**Achieved environmental benefits**

With this technique, solvent emissions are reduced significantly compared to conventional coating systems with solvent proportions of up to 70 wt-%. The coating process is accelerated and the quality is increased (scratch resistance, high opacity). Due to the fast curing process and the temperature stress during the coating process, there are savings of space and energy is reduced.

**Cross-media effects**

No data submitted.

**Operational data**

For some plastics, a yellowing of pale colourings may be caused by UV curing.

**Applicability**

This is commonly applied. For example, the technique is applied to the coating of reflectors.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002]

#### **3.4.2.7.2 Electron beam curing**

*Repeats information Section 17.8.5.3*

##### **Description**

See Section 17.8.5.3. In general, drying and curing are carried out at a maximum temperature of 80 °C due to the heat sensitivity of the substrate.

##### **Achieved environmental benefits**

No data submitted.

##### **Cross-media effects**

No data submitted.

##### **Operational data**

For some plastics, a yellowing of pale colourings may be caused by electron beam curing.

##### **Applicability**

No data submitted.

##### **Economics**

This technique is currently only used for large surface throughputs because of high investment costs.

##### **Driving force for implementation**

No data submitted.

##### **Example plants**

No data submitted.

##### **Reference literature**

[13, DFIU and IFARE, 2002]

#### **3.4.2.7.3 Use of condensation dryers**

**TWG please confirm that this is an applied technique and provide more information**

##### **Description:**

Condensation driers can be used for drying layers of water-based coating systems.

##### **Achieved environmental benefits:**

About 25 % of the supplied energy can be saved, compared to the use of conventional driers as a subsequent cooling zone is not necessary. If the deionised water flows in a closed loop, the generation of waste water can be avoided in the cleaning section. Also, the consumption of fresh water can be reduced by using cascade flow.

##### **Cross-media effects:**

No data submitted.

##### **Operational data:**

No data submitted.

##### **Applicability:**

No data submitted.

##### **Economics:**

No data submitted.

##### **Driving forces for implementation:**



No data submitted.

**Example plants:**

No data submitted.

**Reference literature:**

[13, DFIU and IFARE, 2002]

### 3.4.2.8 Waste gas treatment

**Electrostatic filter**

*Repeats Section 17.10.4.4.*

**Venturi particle separation**

*Repeats Section 17.10.4.1*

**Scrubber**

*Repeats Section 17.10.4.1.*

**Treatment of waste gases from the printing booths**

*Repeats information in Section 17.10.2.1).*

**Description**

~~The painting booth's waste gases can be captured and treated. An effective reduction of VOC emissions can be achieved by the capture and treatment of the painting booth's waste gas flows (see Section 17.10.2.1).~~

**Achieved environmental benefits**

~~Reduction of VOC emissions.~~

**Cross-media effects**

~~The system is relatively inefficient due to the high air volumes that need to be treated and the relatively low VOC concentration, especially for manual applications where high air volumes are required for workplace safety.~~

**Operational data**

No data submitted.

**Applicability**

No data submitted.

**Economics**

~~Reported to be expensive due to the need for waste gas collection and the use of energy in extraction and possibly in supporting combustion.~~

**Driving force for implementation**

~~SED and other legislation. Emission limits in some Member States can be achieved without the need for waste gas treatment.~~

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002], [38, TWG, 2004]

#### 3.4.2.8.1 Concentration and recirculation of waste gases from the painting booths

*Information specific to plastics. Proposed to keep it.*

### Description

Some manufacturers of plastic workpieces prefer to continue the use of solvent-based coating materials. This is because of the specific technical requirements (i.e. characteristics of plastic substrates, customer specifications, flexibility in use, ability to use wet-on-wet processes).

To assist in achieving low solvent emissions, the plastic coating industry concentrates the waste gas streams externally by means of rotating adsorbers (see Section 17.10.3.3). They also use internal recirculation in spray booths with automatic application of the paint.

The exhaust air of a spray booth (typically 40 000–80 000 m<sup>3</sup>/h) is recirculated after intense filtration (typically a venturi wet scrubber plus an additional filtering step) which achieves particle concentrations below 0.1 mg/m<sup>3</sup> in order to avoid optical surface defects on the workpieces. By reheating the exhaust behind the wet scrubber, stable climatic conditions (about 70 % relative humidity) can be achieved. By achieving 90–95 % recirculation of air volumes, the solvent concentration in spray booths is multiplied ~~increased~~ by 10 or 20 (typically from 250 mg/m<sup>3</sup> to 2.5 g/m<sup>3</sup>). The solvent concentration then has to be controlled for safety reasons (to remain sufficiently below lower explosion limits) and for technical reasons (the influence on the evaporation of solvents from workpieces). Between 5 % and 10 % of air volumes is sent to abatement. The low air volume and high solvent concentration are good preconditions for thermal oxidation.

### Achieved environmental benefits

Reduction of VOC emissions.

### Cross-media effects

No data submitted.

### Operational data

No data submitted.

### Applicability

Recirculation of air streams with increased solvent concentration is only suitable for installations which allow effective enclosure of spray booths (small inlet and outlet openings), where application is performed by automatic devices, and for workpieces without internal space volumes. It is therefore not applicable for car bodies, truck cabs and similar objects. Where appropriate, about 90 % reduction of VOC emissions can be achieved.

### Economics

Reduced cost of thermal treatment, due to lower volumes, and higher VOC concentration achieve autothermal conditions.

### Driving force for implementation

IED. See Economics, above.

### Example plants

Volkswagen, Wolfsburg, Germany.

### Reference literature

[119, May, 2006]

#### 3.4.2.8.2 Thermal oxidation

See Section 17.10.5.2.

#### 3.4.2.8.3 Biological treatment

See Section 17.10.7.

### 3.4.2.9 Waste water treatment

#### 3.4.2.9.1 Ultra and nanofiltration

See Section 17.11.8.

Wet separation spray booths are used and equipped with an ultrafiltration unit to separate the paint material, which is then recovered.

*TWG please confirm that this is still valid information*

[13, DFIU and IFARE, 2002]

### 3.4.3 Coating of trains

[13, DFIU and IFARE, 2002] [38, TWG, 2004]

In Chapter 17, techniques are discussed which might also be applicable to the coating of trains. In Section 17.7, techniques relevant to paint application are discussed. These techniques may also be applicable to the coating of trains. In Table 3.16 the general techniques relevant for the coating of trains that are described in Chapter 17, and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1

**Table 3.16: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

#### **Conventional solvent-based materials**

*Conventional techniques have been deleted if they can no longer be considered BAT.*

*This does not prohibit their use or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumption or emissions.*

**Description:** Conventional solvent based paints are: filler (based on polyurethane), primer, topcoats and clear coats.

Typically, the solvents in the waste gas from the dryers and spray booths are not treated. In some situations, waste gases from the dryers are treated by thermal oxidation.

A reported VOC emission factor when applying solvent based systems (without emission controls) is 326 g/m<sup>2</sup>.

**Achieved environmental benefits:** None are reported.

**Cross media effects:** Higher VOC emissions than other coating systems.

**Operational data:** Curing times are shorter than those required for water based systems. Therefore, faster line speeds can be achieved in smaller areas due to reduced oven lengths. Solvent based systems can also operate over a wider temperature and humidity range. Stainless steel equipment is not required. It is common practice to treat the waste gases containing solvent.

**Applicability:** Solvent based paints can be used in all phases of the painting operation (ground coat, filler, solid topcoat, base coat, clear coat and repair). They can be used on metals and plastics. They can be applied to new and existing paint shops where space and cost are prohibitive and where material changes may not be technically possible.

**Economics:** No data submitted.

**Driving force for implementation:** Economic and technical restraints on existing paint shops and certain new paint shops make solvent technology a preferred option for certain facilities. Increasing quality targets are also driving the use of solvent technology.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002] [68, ACEA, 2004] [38, TWG, 2004] [78, TWG, 2005]

### 3.4.3.1 Substitution of solvent-based materials

#### 3.4.3.1.1 Water-based paints

##### Description

For a general description, see Section 17.7.2.2. The following water-based paint systems are applied for the coating of trains:

- ground coat: 3 - 5 wt-% organic solvent, two-component, chromate-free, based on epoxy;
- filler: 3 wt-% solvent content, two-component, based on epoxy;
- topcoat;
- underbody protection layer.

##### Achieved environmental benefits

Reduction of VOC emissions.

##### Cross-media effects

No data submitted.

##### Operational data

No data submitted.

##### Applicability

Water-based paints are normally not applied as topcoats. However, Deutsche Bahn AG uses water-based ground coats, fillers and topcoats for maintenance operations.

Even though water-based topcoats (one-coat topcoat and metallic) with equal properties are available, they are still not accepted by the customers and, therefore, applied only sporadically.

##### Economics

No data submitted.

##### Driving force for implementation

No data submitted.

**Example plants**

Deutsche Bahn AG, Germany.

**Reference literature**

[13, DFIU and IFARE, 2002]

**3.4.3.1.2 High-solid paints****Description**

For a general description, see Section 17.7.2.1.

**Achieved environmental benefits**

Reduction of VOC emissions.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

High-solid paints are only applied in the one-coat topcoat and have a solvent content of 45 wt-%.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004]

**3.4.3.1.3 Coil-coated materials****Description**

For a general description, see Section 17.7.2.9. Coil-coated materials can be applied to parts replacing the spraying processes.

**Achieved environmental benefits**

Significant reduction of VOC emissions dependent on the spraying activities that are replaced by applying coil-coated materials.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

Coil-coated materials are being used increasingly for the production of trains, carriages and wagons.

### **Economics**

No data submitted.

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

### **Reference literature**

[13, DFIU and IFARE, 2002]

## **3.4.3.2 Paint application techniques and equipment**

### ~~Conventional high- and low-pressure spraying~~

#### **3.4.3.2.1 High-volume low-pressure spraying (HVLP)**

For a general description, see Section 17.7.3.12. This paint application technique is commonly applied.

### ~~[Airless spraying]~~

~~For a general description, see Section 0. This paint application technique is commonly applied.~~

#### **3.4.3.2.2 Electrostatically assisted compressed air, airless and air-assisted spraying**

For a general description, see Section 17.7.3.14. This paint application technique is commonly applied.

#### **3.4.3.3 Minimisation of raw material consumption**

Automated mixing systems, i.e. online mixing for two-component products, are used. For a general description, see Section 17.2.4.1.

#### **3.4.3.4 Waste water treatment**

##### **3.4.3.4.1 Ultra and nanofiltration**

For a general description, see Section 17.11.8. Ultra and nanofiltration are both applied.  
[13, DFIU and IFARE, 2002]

#### **3.4.3.5 Waste gas treatment**

##### **3.4.3.5.1 Wet separation spray booths**

See Section 17.10.4.1.

#### 3.4.3.5.2 Venturi particle separation

For a general description, see Section 5.4.5.1. Venturi systems are used to improve the efficiency of the absorption equipment (see Section 5.4.5.2). [13, DFIU and IFARE, 2002]

#### Scrubber

For a general description, see Section 17.10.4.1. Spray booths are applied, see Section 17.10.4.1. However, no information was made available on how waste gases are treated. Emission values of  $< 3 \text{ mg/m}^3$  of dust from the spray booths are reported. [13, DFIU and IFARE, 2002]

#### Dry particle filter systems

For a general description, see Section 17.10.4.5. Emission values of  $< 3 \text{ mg/m}^3$  of dust from the spray booths are reported. [13, DFIU and IFARE, 2002]

#### Electrostatic filter

For a general description, see Section 17.10.4.6. Emission values of  $< 3 \text{ mg/m}^3$  of dust from the spray booths are reported. [13, DFIU and IFARE, 2002]

#### Thermal oxidation

For a general description, see Section 17.10.5.2. In some installations, thermal oxidation units are used for treating the waste gas from the dryers. However, only 20 % of the total solvent input is emitted from the dryers. The other 80 % of the solvents are emitted as fugitive emissions or end up in the waste. Waste gas from spray booths is not treated. [13, DFIU and IFARE, 2002]

### 3.4.4 Coating of agricultural and construction equipment (ACE)

[13, DFIU and IFARE, 2002] [41, ISACOAT, 2004] [78, TWG, 2005]

In Chapter 17, techniques are discussed which might also be applicable to the coating of agricultural and construction equipment. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to the coating of agricultural and construction equipment. In Table 3.17, the general techniques relevant for the coating of agricultural and construction equipment that are described in Chapter 16 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

**Table 3.17: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3

Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

#### ~~[Conventional solvent-based materials]~~

~~**Description:** Conventional solvent based coatings for spraying can be acid hardened alkyd, polyester, PVB, 1 coat topcoat or 2 component topecoat (50 % organic solvents). For dipping, chlorinated hydrocarbons are still used as well as non chlorinated solvents with alkyd resins. See Section 0.~~

~~**Achieved environmental benefits:** No data submitted.~~

~~**Cross-media effects:** Chlorinated hydrocarbons with the risk phrases R45, R46, R49, R60 and R61 are harmful to human health. Those with the risk phrase R59 are ozone depleting substances.~~

~~**Operational data:** Dipping is still commonly applied. Manual spraying with electrostatic HVLP spray guns gives a layer thickness of approx. 25 µm. The overspray is deposited dry. Drying takes place in a convectional drier in which waste gases are treated by a post-combustion unit.~~

~~**Applicability:** No data submitted.~~

~~**Economics:** Costs for traditional coating materials (chlorinated dip coatings, PVB based coatings) used to be extremely low in terms of kilograms or litres compared to alternatives like epoxy based primers and electrocoating. Nevertheless, it can be shown, that in terms of cost per square metre or per coated object, the total process cost of new technologies is fairly competitive (including material consumption, capital cost and depreciation, workforce, energy and other process costs). This is especially true if an adequate use of the installed capacity can be achieved.~~

~~**Driving forces for implementation:** No data submitted.~~

~~**Example plants:** No data submitted.~~

~~**Reference literature:** [13, DFIU and IFARE, 2002, 38, TWG, 2004] [41, ISACOAT, 2004] [78, TWG, 2005]~~

#### 3.4.4.1 Replacement (substitution) and reduction of solvent-based materials

##### 3.4.4.1.1 Water-based paint systems

###### Description

For the general description, see Section 17.7.2.2. Water-based paint systems are applied for:



- electrocoat: 2–6 wt-% solvent content;
- one-coat topcoat: 11 wt-% solvent content.

#### Achieved environmental benefits

No data submitted.

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

Water-based paint systems are commonly applied in electrocoating and in the one-coat topcoat.

#### Economics

No data submitted.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

[13, DFIU and IFARE, 2002]

### 3.4.4.1.2 Powder coating

#### Description

See Section 17.7.2.8. One manufacturer has replaced the conventional top coating process with a solvent-based coat by powder application. An innovative new bath care and rinse-water system is used with aqueous cleaning before further surface treatment. After the pretreatment, the workpieces are coated with a water-based dip coat at first, thereafter with a powder topcoat.

#### Achieved environmental benefits

Reduced VOC emissions, and solvent and energy consumption. Table 3.18 shows solvent and energy consumption data from two installations, i.e. old and new.

Table 3.18: Solvent and energy consumption data from two installations, i.e. old and new

	Old installation	New installation
<b>Solvent consumption</b>	41 g/m <sup>2</sup>	13.6 g/m <sup>2</sup>
<b>Total energy</b>	49.97 MWh/yr	27.73 MWh/yr
<b>Specific energy for drying</b>	6.84 kWh/m <sup>2</sup>	5.48 kWh/m <sup>2</sup>

#### Cross-media effects

No data submitted.

#### Operational data

The surface is coated before assembly of the vehicle takes place. The waste gas of the preceding cathodic immersion prime coat and of the dryers after the primer and powder coating is led through a regenerative oxidiser. Emission values below 20 mg C/m<sup>3</sup> are reached.

#### Applicability

Applicable in new installations.

### Economics

Capital investment for a new powder coating installation is EUR 1.35 million. The process works highly economically.

### Driving force for implementation

IPPC Directive, Solvent Emissions Directive 1999/13/EG.

### Example plants

CLAAS Selbstfahrende Erntemaschinen GmbH, Germany.

### Reference literature

[13, DFIU and IFARE, 2002] [54, Germany - DE, 2004]

#### 3.4.4.1.3 Coil-coated material

See Section 17.7.2.9. Some manufacturers apply electrocoating and topcoating before assembly takes place; coil-coated materials might be an option here.

[13, DFIU and IFARE, 2002]

#### 3.4.4.2 Paint application techniques and equipment

The spraying of agricultural and construction equipment is done manually, by dipping, using conventional pneumatic and electrostatic HVLP spraying techniques, see Section 17.7.3.12 respectively. However, no further information was made available on which of the following spraying techniques and equipment are applied:

- electrostatically atomising spray processes, see Section 17.7.3.9;
- electrostatically assisted high rotation discs and bells, see Section 17.7.3.13;
- electrostatically assisted compressed air, airless and air-assisted spraying, see Section 17.7.3.14;
- ~~processing of powder coatings electrostatically assisted spraying, see Section 0;~~
- wet separation spray booth, see Section 17.10.4.1;
- ~~water emulsion techniques in spray booths, see Section.~~

#### [Conventional dipping]

~~**Description:** See Section 0. Dipping is used for the application of 1 coat topcoats. Layers of 85 µm are commonly achieved.~~

~~**Achieved environmental benefits:** No data submitted.~~

~~**Cross-media effects:** Compared to spraying, thicker coating layers are achieved which might consequently result in a higher consumption of raw material, even if efficiency is low due to spray applications. With dipping, a thickness of 85 µm is usually achieved, and a layer thickness of 50 µm can be achieved when applying spray coating (HVLP).~~

~~**Operational data:** Some manufacturers apply topcoats (and electrocoats) onto workpieces before assembly takes place. In addition to other advantages, more automated processes can be used. However, dip coating needs a certain minimum throughput (coated surface) in relation to the tank volume in order to avoid durations of more than a year for the complete replacement of the tank content.~~

~~**Applicability:** No data submitted.~~

~~**Economics:** No data submitted.~~

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002, 41, ISACOAT, 2004]

#### 3.4.4.2.1 Electrocoating (e-coat)

##### **Description**

See Section 17.7.2.3. All electrocoatings used are water-based; their content of organic solvents is typically 2–6 wt-% and they are lead-free.

##### **Achieved environmental benefits**

An efficiency of approximately 98 % can be achieved.

##### **Cross-media effects**

In the coating of agricultural and construction equipment, it was found that the energy demand for phosphating and ground coat applications via dip coating was significantly higher than conventional pretreatment and paint applications. Therefore, the CO<sub>2</sub> emissions are also respectively higher.

##### **Operational data**

Some manufacturers apply dip coats (and topcoats) on workpieces before assembly takes place. In addition to other advantages, more automated processes can be used.

##### **Applicability**

At present, electrocoating is widely used for the application of electrocoatings.

##### **Economics**

Electrocoating implies high investment and material costs. Wage savings can possibly be made by the implementation of automated processes.

##### **Driving force for implementation**

No data submitted.

##### **Example plants**

No data submitted.

##### **Reference literature**

[13, DFIU and IFARE, 2002]

#### 3.4.4.2.2 High-volume low-pressure spraying (HVLP)

##### **Description**

See Section 17.7.3.12. The substitution of dip coating by spray application for topcoatings shows that cycle times can be reduced, which will also reduce the costs.

##### **Achieved environmental benefits**

No data submitted.

##### **Cross-media effects**

No data submitted.

##### **Operational data**

No data submitted.

### **Applicability**

The use of HVLP spray guns is still very limited. Application efficiencies of over 50 % are to be expected.

### **Economics**

No data submitted.

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

### **Reference literature**

[13, DFIU and IFARE, 2002]

### **[Training]**

*Delete as repetition*

~~**Description:** New coating systems (such as waterborne, high solids) need adaptation of application attitudes, as otherwise filmbuilds are applied too thickly. In general, new coating materials often show restricted application windows; thus technical installations and operator skills have to be improved.~~

~~**Achieved environmental benefits:** No data submitted.~~

~~**Cross-media effects:** No data submitted.~~

~~**Operational data:** No data submitted.~~

~~**Applicability:** No data submitted.~~

~~**Economics:** No data submitted.~~

~~**Driving forces for implementation:** No data submitted.~~

~~**Example plants:** No data submitted.~~

~~**Reference literature:** [41, ISACOAT, 2004]~~

#### **3.4.4.2.3 Batch painting/colour grouping**

This technique is commonly applied as the number of colours applied is usually limited, see Section 17.6.3.1.

#### **3.4.4.3 Waste gas treatment**

The following techniques are commonly applied:

- The solvents in the waste gas from the dryers are extracted, reduced or destroyed (see Section 17.10.2.6), depending on the throughput of the installation and the emission levels.

- Dry particles filter systems, see Section 17.10.4.5. ‘Dry removal’ of paint particles is applied.
- Electrostatic filter, see Section 17.10.4.6. ‘Dry removal’ of paint particles is applied.

#### 3.4.4.4 Waste water treatment

The following techniques are commonly applied:

- ultra and nanofiltration are commonly applied to the electrocoating dip baths, see Section 17.11.8;
- reverse cascade rinsing, see Section 17.4.1.3;
- use of ion exchanger, see Section 17.4.1.5 ;

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## 4 COATING OF SHIPS AND YACHTS

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005] [202, SEA SMRC, 2017]

### 4.1 General information on the coating of ships and yachts

Ships are largely constructed from shipbuilding steel, and yachts are constructed from shipbuilding steel and aluminium, as well as FRP (fibre reinforced plastics). These materials corrode or deteriorate if unprotected and must, therefore, be preserved by means of corrosion protection systems. The required costs in the case of ship construction amount to about 3–7 % of the total construction costs. Corrosion protection enhances ship safety during passage, maintains the ship's value and reduces maintenance costs. Different parts of a ship, e.g. the hull (above and below water), outside decks, hold and tanks, are exposed to a varying degree of corrosion so that different corrosion protection systems are applied. Fouling prevention by the application of anti-fouling is also important. Resistance to mechanical action on surface areas and decks, and visual quality in various areas are also key factors in the specification of coatings.

The requirements for the coating of ships and yachts are different. For the coating of merchant ships, adhesion, corrosion protection and prevention of fouling are the key issues. For the coating of yachts, appearance also plays a crucial role, therefore, the coating of merchant ships and yachts are described separately. Due to different construction, coating and pretreatment processes, the coating of new ships and the repair and maintenance are also considered separately. No information on the coating of warships has been submitted.

In 2015 European shipyards constructed, maintained and repaired ships with a value of more than EUR 33 billion. The maritime equipment manufacturers, who highly depend on building, maintaining and repairing ships in Europe, contribute to another EUR 47 billion of turnover. The European ship repair activities amounted to a total turnover of EUR 3 billion in 2015. All combined this adds to a direct employment of about 450 000 people and more than 22 000 companies.

In 2004/2015, European shipyards completed 360 ships, representing more than 4 million CGT (compensated gross tonnes), 17 % of the world market share in volume, constructed, maintained and repaired ships with a value of more than EUR 10000 million EUR 33 billion – about 30 % of world turnover. Of the total volume in CGT, 26 % was container ships, 24 % passenger ships and 12 % product and chemical carriers. The European ship repair activities amounted to a total turnover of EUR 1900 million in 2004. The maritime equipment manufacturers, who highly depend on building, maintaining and repairing ships in Europe, contribute to another € 47 billion of turnover. The European ship repair activities amounted to a total turnover of € 3 billion in 2015. All combined this adds to a direct employment of about 450.000 people and more than 22.000 companies.

The EU's recreational boating industry comprises with 32 000 direct companies, 280 000 direct employees, and more than EUR 20 billion in annual manufacturing turnover. From the 32 000 companies approximately 90 % of these businesses are SMEs. This figure is including repair and maintenance of super yachts, marine engine manufacturers, marine and yacht coat manufacturers and applicators, high technology electronics companies and equipment manufacturers. But excludes the super yacht new build sector which has for 2016 an order book of 424 with an average length of 48 meters.

## 4.2 Applied processes and techniques in the coating of ships and yachts

Coating systems consist of one or more layers of solvent-based, low solvent or non-solvent coatings. The bonding agent bases are predominantly epoxy resin (usually 2-component), polyurethane, acrylates, polysiloxanes and alkyds. The total layer thickness is 100 µm or higher for ship internal areas and up to 1000 µm for outside areas. A thicker layer of special top coatings are usually applied to ramps and working areas and fillers can be applied at around 2,500 µm. Coating materials are usually applied by means of airless spraying processes, which enable the processing of low solvent and non-solvent products. Application by conventional spray, rollers and brushes is widely used in coating yachts, and rollers are used for pre-delivery coating of passenger ships. They are not widely used in other parts of the industry (with the exception of small areas). Roller and brushes are used for repair, maintenance and so called stripe coating.

For new construction, repair and maintenance of ships and yachts, both the surface preparation and coatings are defined by ship owner specifications. The specification will consider the required corrosion and physical protection, appearance and antifouling, and also the warranty requirements. In repair and maintenance yards, the customer purchases the coats directly for shipyard application.

### 4.2.1 New construction

The coating of ships is mainly carried out by contractors that specialise in corrosion protection for shipbuilding. In modern shipbuilding, sheet metal is made into sections or block stages. These are large sub-assemblies which are then joined together in a building dock or slipway (ships were previously built in the dock from the keel up). These are then coated after surface pretreatment with a coating system according to the specification. Multiple coating of the sections takes place in the open air, in large shipbuilding halls (usually a covered dry dock or covered slipway) or in specially equipped blasting and coating shops. Areas left free of coating for welding are finished on the completed hull on the stocks or in the dock. In smaller shipyards, the hull is completely coated once it is assembled on the stocks or in the dock.

Corrosion protection begins with primary surface pretreatment according to standard specifications on degrees of preparation. All steel plates and sections used to construct the ship are completely cleaned of mill scale, rust and other impurities through blasting in automated plants. This gives the steel surface a specific roughness to ensure good coating adhesion. Subsequently, a shop primer (solvent- or water-based) is sprayed on which protects the steel until further coating is applied as well as enables to weld the steel. Steel plates and sections are often treated with a shop primer by the supplier. Surface treatment of the assembled steel plate sections, or of the complete hull, is carried out by secondary surface preparation, which can be partial blasting with a dry or wet agent, power tool (rotating wire brush or disc) or by angle grinding. This removes corrosion on welding seams as well as all impurities, and roughens the surface. Since not all impurities, like grease, oil or salt, can be removed by derusting, suitable methods for cleaning need to be considered, like cleaning with solvent or cleaner to remove oil and grease or fresh water to remove salt. At several shipyards, sections are treated in dedicated blasting and coating shops.

In enclosed areas, ventilation systems are used and may include dust and VOC abatement. Blasting grits can be collected and treated for reuse and/or recycling.

The coating of yachts is carried out either by a specialist team within the yard or by specialist sub-contractors who can achieve the quality of finish required for the yachts. Increasingly, water-based shop primers are being used for both steel and aluminium yachts. The application process of super yachts is according ISO standards.



## 4.2.2 Ship repair and ship maintenance

Repair and maintenance (including coating) of the hull is carried out during dry docking in graving (concrete) or floating (steel) docks. Depending on the condition of the surface, the damaged areas are cleaned and recoated, or the coat is completely removed from the hull for recoating. Cleaning of the areas to be treated can be by dry or wet blasting or high pressure fresh water jetting.

The coats are specified by the ship owners. Large repair yards may treat four or more ships simultaneously, with coats specified from different suppliers. Application of coats contributes up to 15% to the turnover of repair and maintenance yards. Next to this a lot of additional work is done by the yard when the ship is being coated. This work contributes to a multiple of the turnover for coating but is only done at that yard as the ship is undergoing coating. In this way application of coat indirectly contributes to a far higher percentage of the turnover than for the coating alone.

## 4.2.3 Coating of ships

The preparation for, and application of, coatings for new build construction and for maintenance is usually in areas open to the outside air.

### Corrosion protection of the hull

Coating is carried out according to the maintenance and docking plan of the ship. Coating systems are chosen by the ship owner taking into account the lifetime of the antifouling coating and the required corrosion protection and colour. The areas to be coated are degreased, prepared and the specified coatings (usually epoxy coatings, polyurethanes and acrylics) are applied. This is usually done by airless spray. ~~In critical areas, such as the whole external area, in holds and water tanks, single and multilayered epoxy resin (2 component) coatings are generally used. Chlorinated rubber coatings are rarely used, as the chlorinated solvents used are controlled by EU regulations.~~ The coatings meet visual requirements, such as colour and gloss, as well as resistance to mechanical and corrosion action. Coating materials are generally supplied in 20 litre cans, although for large scale applications, 1000 litre re-usable (IBC) containers can be used.

### Tie coat (hull)

As a tie coat (coupling agent) between the corrosion protection coat and the final coat of antifouling coat, a solvent-based, 1- or 2-component vinyl resin or epoxy tie coat is applied. ~~For some paint systems, a coupling agent is not necessary if the application of the antifouling paint is undertaken within 36 hours after the application of the corrosion protection material, although this technique (wet on wet) is rarely used.~~ The tie coat is also applied via the airless spraying technique. The layer thickness amounts to approximately 75 - 100  $\mu\text{m}$ .

### Antifouling (hull)

[78, TWG, 2005] [123, KiiI, et al., 2006/07] [202, SEA SMRC, 2017]

Antifouling coats are applied to ship hulls to prevent settlement and growth of fouling organisms (bacteria, algae and animals). This can in some cases also be done by applying fouling release coatings (see 11.4.7.1). Settlement of fouling increases the surface roughness leading to increased frictional resistance, which in turn leads to increased fuel consumption to keep the same speed or decreased speed at the same fuel consumption. Up to 150 kg of organisms can settle on one  $\text{m}^2$  surface area within six months. The increased frictional resistance can raise the fuel consumption and thereby the ships emissions by up to 40 %. This will result in either increased bunker costs or expenses due to lost earnings or time delays. Fouling of the ship hull also decreases the manoeuvrability of the vessel and increases the possibility of premature corrosion. Further, by applying antifouling coat the

potential for transmigration of fouling organisms is also decreased. Therefore, application of antifouling is a matter of importance from environmental, safety and economical aspect.

Regulation (EU) No 528/2012<sup>18</sup> regulates the use of biocides and biocidal products e.g. antifouling in Europe. Worldwide the use of antifouling coats is regulated by the IMO International Convention on the Control of Harmful Anti-Fouling Systems on Ships that prohibits the use of harmful organotins in anti-fouling coats used on ships and establishes a mechanism to prevent the potential future use of other harmful substances in anti-fouling system. At the date this Convention only considers organotins as harmful substances.

The antifouling coatings predominantly used today contain organic and inorganic biocides incorporated into a binder system. The biocides are released from the paint in a controlled manner creating a microlayer of sufficient concentration over the hull surface to prevent the organisms from settling onto it. Up until 2003, most of the antifouling paints used organotin compounds as biocides incorporated into the self polishing binder system. Due to increased concern about the reported adverse effects in the marine environment (e.g. on certain snails and oysters), the International Maritime Organisation (IMO), a UN body, placed TBT on the work programme during the 1990s. In October 2001, IMO adopted the International Convention on the Control of Harmful Anti Fouling Systems on Ships banning the application of TBT based paint on ships from January 2003. From 1 January 2008 the use of active TBT based paint is prohibited which means that any TBT based paint on the ships hull must either be sealed off or removed by that date. In the EU, this ban was enforced by an amendment to the Marketing and Use Directive whereby application of tin based paint was banned in EU shipyards by 1 January 2003. Further, an EU Regulation was implemented which in principle implements the IMO Convention in all EU countries from 1 July 2003. Today the major antifouling paint manufacturers have phased out TBT based antifouling paints from their product ranges.

The organic biocides used in current IMO compliant antifouling paints (1–10 wt %) are rapidly degraded once they are released from the paint surface. Almost all antifouling paints contain copper of up to 50 wt % as the main biocide. Copper is a metal and not biodegradable, but most of the dissolved copper is complexed with organic and particulate matter in the water and the availability to organisms is thereby reduced or completely removed. Sedimentation removes the complexed copper into the sediment compartment where it is tightly bound to organic matter and inorganic compounds.

Every two to five years, the antifouling coating on the ship's hull is renewed in dry dock depending upon the type of coating and the service time of the vessel. The remains of the exhausted paint are usually removed by blasting (grinding or brushing may be used in some cases) and the anticorrosion paint is repaired. Subsequently, the complete hull is coated with a solvent based antifouling paint applied by airless spraying in a dry film thickness of 150–500 micron per coat, depending upon the specification. The overspray is partly emitted into the environment via wind, in the runoff from rainfall or via flooding of the dry dock, or collected, depending upon the control measures in force.

The dry film thickness of the complete paint system on the hull including the anticorrosive coatings, the tie coat and the antifouling paint is approximately 500–1 000 micron (0.5–1 mm).

### **Coating of the superstructure and freeboard**

Also for the superstructure and freeboard the coating systems are chosen by customer. The damaged areas are degreased, prepared and coated with the specified coats (usually solvent based epoxy coatings, polyurethanes, acrylics) usually applied by airless spray. In holds and water tanks, single and multilayered epoxy resin (2-component) coatings are generally used.

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<sup>18</sup> REGULATION (EU) No 528/2012 of the European Parliament and the Council of 22 May 2012 concerning the making available on the market and use of biocidal products

A solvent based, two component, polyurethane ground coat can be sprayed onto the primer layer; however, many other systems are also available. Generally, two layers each of 60  $\mu\text{m}$  are applied. On top of the ground coat a two component, solvent based polyurethane material is then applied in two layers. Each layer has a thickness of 40  $\mu\text{m}$ . The layer thickness of the complete paint amounts to approximately 250–300  $\mu\text{m}$  for the superstructure. Alternatively, a two layer system consisting of epoxy resin, 170 micron, and a flexible high solids polyurethane topcoat, 80 micron is also used.

#### 4.2.4 Coating repair and maintenance of yachts

Yachts are leisure vessels with a length of up to 180 m, although there have been recent developments of up to 190 m and 200 m. Yachts are already partly coated before assembly. Depending upon customers' requests, the applied coating system varies and for this reason only one option is described in the following paragraphs.

Yachts are made of shipbuilding steel and aluminium, although the majority of yachts (the smaller vessels) are made from FRP (fibre reinforced plastic). Parts of the whole yacht or only the superstructure may be made of aluminium or composite materials. Sanding takes place between the application of coating layers. Depending on the material, pretreatment and application of the primer are different. The use of water-based materials for coating yachts is increasing as well as other new ways of coatings like wrapping (foil application).

Although airless spraying is widely used and accepted, rollers and brushes are still in use, depending kind of coating used and quality required.

##### **Pretreatment and primer application on shipbuilding steel**

Firstly the hull and the superstructure are treated via grit blasting and then either a filler based on zinc phosphate or a chrome- and zinc-free shop primer is applied as a primer in order to obtain the correct profile and a smooth finish (e.g. covering welding roughness). Both materials are solvent-based epoxy resins. The layer thickness varies from 40–60  $\mu\text{m}$ .

##### **Pretreatment and primer application onto aluminium**

For the degreasing and removal of oxidised layers, aluminium surfaces are treated with cleaning agents. Afterwards, a two-component epoxy primer or a one-component PVC primer is applied. Similarly to the coating of ships, corrosion protection coat is sprayed onto the primer layer. This solvent-based epoxy material is applied by the airless technique in two to four layers with a thickness of approximately 120  $\mu\text{m}$  each. The antifouling is usually applied directly to the epoxy coat. If a tie coat is used, it is a solvent-based, one-component vinyl coat, which is applied via airless-spraying. The layer thickness amounts to about 40  $\mu\text{m}$ .

Afterwards, two layers of a solvent-based antifouling material are applied by airless spraying or by roller. The layer thickness of the antifouling coating amounts to approximately 100  $\mu\text{m}$  for each layer. Usually copper-based, self-polishing antifouling coatings are used. However, they may also contain other biocides.

##### **Coating of the superstructure**

Like the hull, the superstructure is made of shipbuilding steel or aluminium is also coated with two layers of a solvent-based (one- or two-component epoxy or polyurethane coat) corrosion protection material. It is applied using the airless-spraying technique. The applied layer thickness amounts to about 120  $\mu\text{m}$ .

After the corrosion protection coat has dried, filling materials are applied onto aluminium and shipbuilding steel of the superstructure in order to obtain the correct profile and a smooth finish (e.g. covering welding roughness). The materials are applied using trowels, long boards and batons, spatulas. They may be solvent-free or contain approximately 80 g/l benzyl alcohol. Sanding takes place in between these processes.

After the filling, a solvent-based two-component polyurethane filler or a solvent-based epoxide filler is applied by using airless spraying techniques. The layer thickness applied is in the range of 50–100 µm. A primer/undercoat is applied over the filler.

The yacht is taken for sea trials when the appropriate coat has dried; this may or may not be the primer coat. After the trials, the yacht is cleaned with fresh water and sanded and then the final topcoat is applied.

The topcoat is applied by using a wet-on-wet spraying technique, and two or three layers are applied. The materials used are generally solvent-based, two-component, polyurethane combination lacquers. The complete layer thickness amounts to approximately 100 µm.

In several Member States where yachts are repaired or maintained, the removal of antifouling from yachts is carried out using techniques to collect and treat the removed antifouling to prevent water pollution.

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### 4.3 Current consumption and emission levels in the coating of ships and yachts

[155, TWG, 2016] [202, SEA SMRC, 2017]

Data from three installations (one from Finland, one from Portugal and one from the UK) were submitted for the data collection.

#### 4.3.1 Mass balances

Submitted data for two installations show an average paint consumption per m<sup>2</sup> of coated surface that ranges from 0.4 kg up to 2 kg.

Data for one installation (plant #076) on the solvents content shows a considerable variation due to contract quality specifications: 18 wt-%. (2013), 27 wt-% (2014) and 40 wt-%. (2015)

#### 4.3.2 Consumption

##### 4.3.2.1 Materials

[78, TWG, 2005]

For the coating of ships, solvent-based coats are applied. Depending on the material used, the solvent content is in the range 20–40 wt-%. Due to the processing conditions (humidity, temperature, air draught, etc.) and surface conditions, water-based coats have only a limited area of application (only partly used for interior areas and prefabricated parts). Consumption of materials will depend on the size of the vessel, specification to be met, etc.

The material consumption in repair yards for medium sized ships (> 15 000 GT) is approximately 15 tonnes per coated merchant ship (based on data from Portugal, Greece, Malta and Italy). The corresponding VOC usage is approximately 6 tonnes. A large repair yard can repair from 60 up to 150 ships with an average size of 40 000 GT (or above) per year.

In a new-build shipyard, the material consumption for complete coating of one 40 000 GT size ship is approximately 68 tonnes. HDW Kiel in Germany processes up to 59 t solvent/yr for a maximum of five ships a year. Blohm + Voss Repair GmbH in Hamburg, Germany processes about 60 t/yr of organic solvents.

##### 4.3.2.2 Water

[155, TWG, 2016]

In repair and maintenance yards, the consumption of fresh water for high pressure cleaning (between 220 to 340 bar) of the complete hull is varied between 500 to 1000 tonnes for medium sized ships (>15 000 GT).

Reported data on water consumption indicate a specific water consumption that vary between 100 m<sup>3</sup>/m<sup>2</sup> and 1 100 m<sup>3</sup>/m<sup>2</sup> of coated surface.

The reported techniques for reduction of water consumption are:

- control of water usage by applying (ultra-) high-pressure (U)HP water washing at the vessels prior to coating;
- oil skimmer for the treatment of waste water from cleaning.

### 4.3.2.3 Energy

[155, TWG, 2016]

Submitted data on energy consumption show a specific energy consumption range that varies between 0.01 MWh/m<sup>2</sup> and 0.67 MWh/m<sup>2</sup> of coated surface. There are two important parameters that have to be taken into consideration:

- the specific energy consumption is directly related to the degree of utilisation of the production capacity: the greater the throughput the lower the specific energy consumption value; and
- the uncertainty on when the reported energy consumption data refer only to the STS activity or include other unassociated activities (defining of the energy boundaries of the STS activity, see also 17.5.2).

### 4.3.3 Emissions

[78, TWG, 2005], [155, TWG, 2016] [202, SEA SMRC, 2017]

#### 4.3.3.1 Emissions to air

Processes in shipyards are generally carried out outdoors, in dry docks, in open workshops or on the quay. Therefore, all emissions generated by grinding and blasting (dust) or painting operations (overspray and VOCs) are emitted as fugitive emissions.

In repair yards for medium sized ships (>15,000 GT, with an average 70,000 GT), about 150g VOC are emitted per square meter painted, since the paints used contain on average about 30 – 40 % organic solvents (major contribution from antifouling paints, the largest amount of paint applied). In Germany, it was reported that the paints used contain an average of 20 - 25 wt-% organic solvents. About 100 g VOC are emitted per painted m<sup>2</sup>.

~~Therefore, pollutants that are generated by grinding and blasting or painting operations are emitted directly into the environment. Generally, all VOC emissions from painting processes are emitted as fugitive emissions. Beside VOCs, dust from blasting agents (e.g. silicates, or steel or copper sinter), metal particles and overspray have an environmental significance. Where spraying is used and depending on the application conditions, the overspray can mount up to approximately 30 % of the material input. Depending upon weather conditions, the particles from blasting and the overspray can be carried for several kilometres.~~

Emissions of environmentally hazardous materials from coating processes in the new construction of ships can be reduced effectively by the utilisation of closed workshops for coating and blasting operations. These may also be used for the construction of block stages – sections of a new or significantly upgraded ship that are prefabricated and then lifted into place. Closed workshops may have air extraction with filters for dust and/or waste gas abatement units for VOCs.

~~Another option to reduce the dust emitted is the use of water or slurry blasting.~~

~~The amount of overspray has been reduced in open air to 5 % by using mobile application devices with integrated extraction of overspray in one yard. Additionally, further emissions from overspray can be reduced by closing the dockends with nets (to achieve wind reduction).~~

In repair yards for medium sized ships (> 15 000 GT, with an average 70 000 GRT), the coats used contain on average about 30–40 % organic solvents. About 150 g VOCs are emitted per m<sup>2</sup> coated, as the antifouling coats form the largest amount of coat applied. In Germany, it was

reported that the coats used contain an average of 20–25 wt-% organic solvents. About 100 g VOCs are emitted per coated m<sup>2</sup>.

A full coating scheme at a newbuilding superyacht contains for under water area up to 500 g VOC / m<sup>2</sup> and above waterline up to 250 g VOC/m<sup>2</sup>. New yacht construction is usually carried out in closed facilities, and also using rollers and brushes, which have a high application efficiency with no overspray. For large (super and mega) yachts, this will be according to the client's specification. Repair and maintenance of the large mega yachts may be done in docks, but for most of them, maintenance and repair are also carried out in closed facilities.

For the two shipbuilding installations that submitted solvent mass balance data, the calculated total VOC emissions expressed against the production throughput varies between 115 g VOC/m<sup>2</sup> and 422 g VOC/m<sup>2</sup>.

As the activity is mainly carried out under non-contained conditions, the fugitive VOC emissions are equal to the total emissions.

The reported figures on the solvent flow in waste (parameter O6 of the solvent mass balance) for the two installations show a range from 5 % up to 60 % of the total solvent input.

#### 4.3.3.2 Emissions to water

Maintenance operations generate contaminated wasted blasting materials agents, coat residues, used containers, and overspray. There may be other residues from maintenance, such as oil residues (containing hydrocarbons), mud, scrapped materials, etc. After maintenance operations all wastes are collected and the dock is cleaned to prevent reduce emissions to the environment water entering the dock. Waste water collected can be treated by several techniques as described in section 4.4.9. The threated water is either disposed of or reused.

Where water blasting or slurry blasting is used to avoid dust emissions from blasting, the process water is commonly treated either in integrated equipment or at a waste water treatment plant. The water may be is usually reused.

~~Where the waste water is contaminated, several techniques can be applied to reduce emissions. The treated water is either disposed of as waste water or reused. These are both described in Section 4.4.9.~~

A COM study<sup>19</sup> identified the main parameters and other substances of interest that may be discharged in waste waters and therefore to be considered for the data collection. These are set out in

Table 4.2 below. However, only two sets of data were received from shipyards: one with a waste water treatment plant and one using coarse filtration.

**Table 4.1: Shipyard sampling information**

Installation	WW treatment	Sampling type	Frequency
075	Combined WWTP	Time-proportional composite	Monthly (COD weekly)
076	<i>In situ</i> coarse filtering in dock bottom with hay bales and hessian	Spot	Twice a month

<sup>19</sup> COM working document EIPPCB 09/06/2016: Assessment of Technical Working Group (TWG) data submitted on metals and other emissions to water for their consideration as Key Environmental Issues for installations carrying out IED Annex 1 6.7 activities.

Table 4.2: Shipyard waste water data

Installation number	TSS	COD	Zn	Cd	Pb	Cu	Cr <sub>total</sub>	TBTO	Sn	Other biocides
075	8.2	39.8	0.08	0.016	NI	0.11	NI	NI	0.02	NI
076	15	NI	0.05	< 0.01	0.01	0.01	0.01	NI	NI	NI
NB: NI = No information. Source: [155, TWG, 2016]										

Although there is insufficient comparable data and information to derive BAT-AELs, the figures indicate that these techniques in combination with dry dock discipline can achieve low emissions.

#### 4.3.3.3 Waste

[202, SEA SMRC, 2017] [155, TWG, 2016]

Waste from the maintenance operations of ships include for example:

- organic cleaning solvents;
- coat sludges/residues; it is reported that waste coats represent a percentage of 2.5 % up to 8.5 % of total paint consumption with an average solvent content of about 30–40 %;
- contaminated coat containers, brushes and rollers;
- used/contaminated blasting materials (e.g. used grit);
- filters;
- used paint containers which are normally sent for recycling;
- oil residues (containing hydrocarbons);
- mud;
- scrapped materials.
- residual water from the cleaning of a dry dock before flooding.

The implementation of large reusable containers (IBC, 1000 litres), instead of 10 or 20 litre single use containers, leads to a reduction of waste containers and the amount of waste paints that remain in old containers. However, this is only applicable for large ships and/or for large amounts of one type or colour of paint. When two component paints are supplied in IBCs, the mixing of paints takes place by means of a precise dosage system with permanent monitoring of the mixture ratio. In cases where several ships are being maintained at any one time, with differing specifications and quantities, or in the case of yachts, these containers are too large for the quantities consumed. In addition, there are problems with settlement of the paints in such large containers.

During the coating of ships, especially in maintenance operations, large amounts of contaminated wasted blasting agents materials are generated. As all the other wastes, wasted blasting materials are disposed of in licensed facilities. Heavy metals and TBT from blasting and grinding dusts are of special environmental significance. Water blasting generates only 1.5 % of the amount of waste arising from conventional grit blasting.



## 4.4 Techniques to consider in the determination of BAT for the coating of ships and yachts

[202, SEA SMRC, 2017] [155, TWG, 2016]

In Chapter 17, techniques are discussed which might also be applicable to the coating of ships and yachts. In Section 17.7, techniques relevant to coat application are discussed. These techniques might also be applicable to the coating of ships and yachts. In Table 4.3, the general techniques relevant for the coating of ships and yachts that are described in Chapter 16 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

**Table 4.3: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### 4.4.1 Management systems – dock discipline

#### Description

The set of procedures, functions and task definitions, and working methods, for the prevention or limitation of emissions such as: dust emissions to air, emissions to water, and quantity of waste produced.

#### Technical description

This is a specific management system defining the different entities responsible for performing works in dry docks and slipways, including the preparation for docking, careening and undocking vessels. It also includes the maintenance, repair or building activities carried out in dry docks and slipways, such as surface treatment operations (cleaning, removal of old coat and antifouling, etc.). It controls the collection of wastes, during operations and before dock flooding and the forwarding of wastes to licensed receivers for their further appropriate management and/or disposal.

Dock discipline also covers other issues that assist in reducing pollution, such as when and where to carry out potential polluting activities. For example, describing in what wind conditions grit blasting and spraying in the open air can be carried out, requiring these activities to be carried out at the bottom of the dock or slipway and portable equipment to be used (nets, water curtains, etc.).

It may contain part of, or all, the requirements of an EMS (see Section 17.1).

**Achieved environmental benefits**

Describes procedures for Minimisation of environmental impacts from the installation.

**Cross-media effects**

None.

**Operational data**

See Technical description, above.

**Applicability**

No data submitted. Generally applicable

**Economics**

No data submitted.

**Driving force for implementation**

Meeting legislation for health and safety and the environment for air pollution, water pollution and waste management, particularly as they apply to ports, harbours and enclosed waters, etc.

**Example plants**

Widely applied in the industry.

**Reference literature**

[78, TWG, 2005] [121, Portugal, 2006] [153, de Vries, 2011]

#### 4.4.2 Techniques to reduce dust emissions Enclosure techniques

**[Open areas]**

*Conventional techniques have been deleted if they can no longer be considered BAT. This does not prohibit their use or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumption or emissions.*

**Description:** Processes in shipyards are generally carried out outdoors, in dry docks, in open workshops or on the quay. Repair and maintenance (including painting) of the hull is carried out during dry docking in graving (concrete) or floating (steel) docks.

**Achieved environmental benefits:** None.

**Cross-media effects:** Pollutants that are generated by grinding and blasting or painting operations are emitted directly into the environment. Generally, all VOC emissions from painting processes are emitted as fugitive emissions. Beside VOCs, dust from blasting agents (e.g. silicates, or steel or copper sinter), metals and overspray have an environmental significance. Depending upon weather conditions, these particles can be carried for several kilometres.

**Operational data:** No data submitted.

**Applicability:** Normal working practice.

**Economics:** No data submitted.

**Driving forces for implementation:** Cost.

**Example plants:** Widely used.

**Reference literature:** [13, DFIU and IFARE, 2002] [78, TWG, 2005] [122, CEPE, 2006]

#### 4.4.2.1 Partial enclosure of treatment areas [~~enclosed areas, windbreaks, spray curtains, etc.~~]

##### Description

Fine nets and water spray curtains can be used around areas where grit blasting and/or airless spray painting are carried out. They may be permanent or temporary.

~~Techniques can be used to act as windbreaks, as such as nets or tenting (described in Section 4.4.2.2) and water spray curtains can be used around areas used for grit blasting, etc. These may be permanent or temporary.~~

##### Achieved environmental benefits

Reduction in emissions of drifting particles from grit blasting and spray coating, either by reducing wind strength or by trapping particles.

##### Cross-media effects

Power for pumping water sprays or curtains, and possible treatment of the waste water.

##### Operational data

There are reports of practical difficulties using nets and the larger the ship in comparison with the dry dock, the more difficult they are to use. They cannot be used in repair yards for medium sized ships (> 15 000 GT) in large dry docks and the following are typical examples of problems encountered:

- variations in the size and type of ship, the ships may overhang the dock ends, etc.;
- interference with cranes and other equipment; and
- problems with access for other maintenance operations.

~~Poor practical results are obtained compared with the cost of encircling the dock.~~ Where used, the nets are ~~therefore~~ usually placed at one or both ends of a dock, around smaller docks or between the ship and the dockside.

##### Applicability

Applicability may be restricted by the shape and size of the area to be enclosed. See Operational data, above.

##### Economics

No data submitted.

##### Driving force for implementation

Low cost compared to full enclosure.

##### Example plants

No data submitted.

##### Reference literature

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005] [122, CEPE, 2006], [154, Nordic Council of Ministers, 2016] [151, CESA 2006]

#### 4.4.2.2 Fully enclosed areas

##### Description

Blasting and/or airless spray painting may be carried out in halls, closed workshops, areas tented with architectural textiles or areas fully enclosed with nets.

##### Technical description

Enclosed areas are used to control the local working environment, enabling temperature and humidity control for working and surface preparation, protection from rain, etc. Enclosed areas usually have air extraction for occupational health reasons, and this can be used in conjunction with waste gas treatments to control the emissions of environmentally harmful materials. The equipment may be abatement for dust and/or with a waste gas abatement unit for VOCs.

Some areas, such as slipways, ships blocks and small docks can be temporarily or semi-permanently enclosed or 'tented in' (e.g. portable structures or tenting kept on site for long periods of time). This assists control of dust from blasting and overspray, but unless the enclosure is sufficiently enclosed, adding waste gas treatment for dust and VOC reduction is likely to require the treatment of large volumes of air with high energy usage. If the enclosure has a flexible construction or is not sufficiently enclosed the extraction for treatment of VOC may not be possible.

Tenting may also be applied between a ship and the dockside, to help prevent the drift of dust and overspray and keep rain off prepared and freshly coated areas.

### **Achieved environmental benefits**

Retention of particles from blasting and spraying. Removal of dust and/or VOCs from the extracted air streams by waste gas treatment becomes possible.

### **Cross-media effects**

Energy used for air extraction.

### **Operational data**

Provides improved quality control of processes and working environment. Can increase available working time during the day and/or year.

### **Applicability**

Applicability may be restricted by the shape and size of the area to be enclosed and quality requirements.

Enclosed halls are more often used for fabrication and building of ships.

Permanent workshops can be used for preparing steel plates, sections and block stages in new construction. In some cases, whole docks may be enclosed. The docks used for the repair and maintenance of ships are not enclosed (and possibly not those used for some mega yachts).

For yachts, the preparation and coatings areas are usually enclosed, either permanently or semi-permanently, both for new build and repair and maintenance, due to the requirements of ISO 19494.

### **Economics**

Capital cost of construction of workshops. Capital costs and running costs of abatement equipment.

### **Driving force for implementation**

Improved quality control of coating processes and internal climate control (i.e. weather protection) allowing for all day/all year working. IED. Legislation for health and safety and dust.

### **Example plants**

HDW Kiel, Germany.

### **Reference literature**

[13, DFIU and IFARE, 2002] [78, TWG, 2005] [122, CEPE, 2006] [154, Nordic Council of Ministers, 2016]

#### 4.4.2.3 Restrictions for adverse weather condition

##### Description

The restriction of blasting and airless spray painting when adverse weather conditions are observed.

##### Technical description

A technique used by yards with no full containment facilities is the restriction of paint removal and airless spray painting when adverse weather conditions are observed. Adverse weather conditions are significant wind speed (variable within each yard, depending on available facilities and their location) and adverse dominant wind direction (e.g. towards water courses, housing and other sensitive targets)

##### Achieved environmental benefits

Reduced dust emissions.

##### Environmental performance and operational information

##### Cross-media effects

None.

##### Technical considerations relevant to applicability

##### Economics

Low cost, requiring only simple monitoring equipment.  
Lost working time when conditions are adverse.

##### Driving force for implementation

Adverse reaction from public affected by dust and overspray.

##### Example plants

Generally applicable where no full containment is in place.

##### Reference literature

[151, CESA 2011]

#### 4.4.3 Surface preparation

In new build and for new materials, the surface requires pretreating to provide adhesion. For repair and maintenance, old coat layers and antifouling are removed, particularly in loosely-adhered and damage areas. The preparation method and technique is defined in the agreed coat specification to an agreed specification, depending on the coating system to be applied and the warranty given with the work and/or coating. For example, the surface roughness using shot blast can be up to 20 µm, and for grit blasting it can be in the range 75–100 µm. Also, not all techniques can be used for all vessel areas, e.g. slurry blasting in a double bottom tank, hydroblasting in a cargo tank refurbishment.

The removal of old paint and antifouling will generate wastes containing these materials, with their associated hazards, for example, antifoulings contain biocides and older antifoulings contain TBT, old paint layers may contain lead and chromates, etc.

Some techniques use an abrasive material to remove the coating layers, of these a few create a large amount of dust are created with some techniques. Some techniques use an abrasive medium to remove the coating layers, and these are either The used abrasive material can be recovered and reused or disposed of as wastes, depending on the technique used. With all

techniques, it is good practice to remove the residues from dry docks before flooding (see dock discipline 11.4.1).

### **[Dry blasting – open system]**

*Conventional techniques have been deleted if they can no longer be considered BAT.*

*This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumptions or emissions*

**Description:** ~~Blasting using compressed air and a dry abrasive medium such as steel grit, silica, shot, etc.~~

**Achieved environmental benefits:** ~~No data submitted.~~

**Cross-media effects:** ~~Creates dust from the removed paint and the abrasive medium.~~

~~For repair and maintenance, the grit consumption per ship is approximately 200 tonnes for a medium sized ship (>15000 tonnes GRT).~~

**Operational data:** ~~This is usually the quickest and cheapest technique per square metre (m<sup>2</sup>).~~

**Applicability:** ~~This is the most commonly used technique in repair yards for medium sized ships (>15000 tonnes GRT). It can be used for the removal of rust and old layers of paint from floors and external sides, for removal of hull fouling and for the removal of loose paint.~~

**Economics:** ~~No data submitted.~~

**Driving forces for implementation:** ~~Cost.~~

**Example plants:** ~~Widely used.~~

**Reference literature:** ~~[38, TWG, 2004] [78, TWG, 2005]~~

#### **4.4.3.1 Dry blasting – closed system, vacuum or shroud blasting**

##### **Description**

This is Dry blasting in closed blasting systems, such as with a suction head and centrifugal blasting using steel grit or shot in closed loop systems with low emissions.

##### **Achieved environmental benefits**

Low dust emissions. The blasting ~~medium~~ material may be ~~is~~ recovered for reuse, therefore there is less waste. Removed antifouling and paint are recovered with the blasting material and separated for disposal.

##### **Cross-media effects**

No data submitted.

##### **Operational data**

Mechanical blasting equipment is operated by hand or fixed to the arms of tool carriers and passed along the area to be treated by remote control.

A typical system for new build preparation may be ~~east steel blasting granules~~ steel shot blasting applied in a closed loop and at a pressure of about 5 bar.

##### **Applicability**

Generally applicable. It can be used for the removal of rust and old layers of coat from decks and external sides including hull. ~~for removal of hull fouling and for the removal of loose paint.~~ Also used in primary surface preparation of steel plates before fabrication.

#### **Economics**

No data submitted.

#### **Driving force for implementation**

Control of dust emissions and health and safety at work. Reduced waste management costs.

#### **Example plants**

Widely used in shipyards and other industries.

#### **Reference literature**

[38, TWG, 2004] [78, TWG, 2005] [122, CEPE, 2006]

### **4.4.3.2 Wet or slurry blasting**

#### **Description**

Blasting with water containing an ~~fine~~ abrasive material, ~~such as a fine cinder~~ (e.g. copper slag ~~cinder~~) ~~or silica~~.

#### **Achieved environmental benefits**

This technique avoids the creation of dust emissions.

#### **Cross-media effects**

Increased waste from the abrasive.

#### **Operational data**

With water blasting techniques, the waste water can be collected in the dock, pumped into tanks and treated ~~(e.g. by settlement)~~ prior to emission. ~~This may be integrated into the slurry blasting equipment. The water and the abrasive can be reused.~~ Additional operation of hosing down with fresh water is necessary to remove the wet abrasive from the surface.

#### **Applicability**

Generally applicable. Slurry blasting might have some limitations in application in enclosed areas (cargo tanks, double bottom tanks) due to heavy mist formation. ~~No data submitted.~~

#### **Economics**

No data submitted.

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

Widely used in shipyards and many other industries.

#### **Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005] [122, CEPE, 2006]

### **4.4.3.3 Ultra-high-pressure (UHP) [fresh] water jetting or blasting**

#### **Description**

UHP blasting is a dustless surface treatment method using extremely high pressure, water and no abrasive. There are also options that combine use of water with an abrasive.

**Technical description**

There are several techniques categorised according to the water pressure used: low pressure water cleaning (< 340 Bar), high pressure water cleaning (340 – 700 Bar), high pressure water jetting (> 700 Bar), ultra-high pressure water jetting (> 2000 Bar). ~~Hydroblasting is carried out at pressures above 700 bar, and UHP (ultra high pressure) hydrojetting up to 20 000 bar.~~ By varying the water pressure, single layers of coat or the entire coat system can be removed. UHP blasting is a dustless surface treatment method using extremely high pressure, water and no abrasive. There are also methods that combine use of water with an abrasive.

UHP blasting is generally considered a fast method compared to traditional dry blasting. Treatment efficiency for UHP blasting can be several times faster (20–30 m<sup>2</sup>/h up to 350 m<sup>2</sup>/h depending on the model) than traditional dry blasting (4–5 m<sup>2</sup>/h). Estimates vary a lot and depend on various site-specific factors and thus can only be considered indicative.

One advantage of UHP blasting is that water penetrates deep into the metal pores allowing an efficient removal of chlorides, much more efficiently than in dry blasting. Also, poorly adhering coating is efficiently removed in UHP blasting since water forces its way through and under the coating, breaking the bond and shearing it off.

In advanced UHP models, the work is carried out remotely. The nozzle is attached to the work surface by vacuum, which at the same time sucks off the removed waste material and waste water. The waste water is treated before discharge or it can be filtered and reused and the sludge can be collected in bags.

The nozzle can furthermore be encapsulated in a box, which further reduces the noise. Use of a robot also minimises the health and safety risks of blasting. This is also an important issue since conditions can be extreme outdoors and in confined spaces such as inside tanks. Shipyard employees are at an increased risk of exposure to toxic dusts, high noise levels, and a range of other health and safety hazards. Also, if UHP blasting is used manually, specific safety clothing is needed because of the extremely high pressure.

**Achieved environmental benefits**

UHP blasting has several environmental advantages. No abrasives are used and dust formed of paint residues is bound in water, which minimises dust and waste generation. Only paint waste needs to be collected and disposed of safely. The amount of waste material to be disposed of can be 1% compared to dry blasting.

Generally, noise is comparable to traditional dry blasting methods, whereas in advanced models noise is efficiently reduced by vacuum or use of a box around the spear head.



**Figure 4.1: Box around the spear head in some more advanced robot models**



Water consumption is small, typically 10–20 l/min. When using a robot, the waste water may also be collected directly in tanks. In some models, water can be collected, filtered and reused, which also means easy separation of waste for controlled disposal.

~~This technique avoids the creation of dust emissions and contaminated blasting agents that require disposal. The water used can be retained and recycled, with treatment if necessary.~~

### Environmental performance and operational data

Emissions are very much case-specific.

An example of maximum emission values for waste water substances from high- and low-pressure washing are given in the environmental permit of Falkvarv in Sweden in Table 4.4.

**Table 4.4: Maximum emission values for substances in waste water from high and low-pressure washing in the environmental permit of Falkvarv in Sweden**

Substance	Maximum emission value
Pb	3 µg/l
Cr	15 µg/l
Cd	0.3 µg/l
Cu	9 µg/l
Ni	45 µg/l
Zn	60 µg/l
Mineral oil (oil index)	5 µg/l
TBT	0.001 µg/l
TOC	10 mg/l
<i>Source: 154, Nordic Council of Ministers, 2016</i>	

### Cross-media effects

Paint waste which may contain removed antifouling or lead or chromium pigments from older coatings require collection and managed disposal.

In repair yards, the consumption of fresh water for the high pressure cleaning (200 bar) of the complete hull is approximately 500 tonnes for medium sized ships (> 15 000 tonnes GT).

~~**Operational data:** With water blasting techniques, the waste water can be collected in the dock, pumped into tanks and treated (e.g. by settlement) prior to emission.~~

### Technical considerations relevant for applicability

Generally applicable. UHP blasting may not be applicable in cold climatic conditions and on new surfaces.

UHP blasting and other wet blasting methods are replacing traditional dry blasting as shipyard operators become more experienced with these technologies. The technologies have both technical and environmental advantages over traditional dry blasting as described above.

The efficiency of UHP blasting varies case by case but is generally considered better than traditional dry blasting. A Finnish shipyard has carried out a comprehensive study to compare UHP and traditional blasting methods and has ended up using UHP blasting (Peled 2013).

Nevertheless, opinions on UHP vary considerably among shipyard operators. There are also strong doubts that UHP blasting is suitable for all surfaces and conditions. UHP water blasting is not applicable in cold climatic conditions, below -5 °C. Furthermore, UHP blasting does not create the same rough surface as dry blasting methods, which is necessary for the following surface treatment processes. Therefore, the technology is generally not applicable for new surfaces. Some repair yards and their clients claim that this also limits the applicability of UHP

in repair yards. One shipyard has commented that their clients demand the use of paints that are not applicable with UHP as a pretreatment method. A paint manufacturer, on the other hand, states that for most purposes a paint that is compatible with UHP blasting can be found. The applicability of UHP blasting together with specific coating needs to be verified from the paint supplier and usually it must also be approved by the client.

One shipyard commented that grit blasting with water injection gives the best result in regard to surface, but in particular to cost. One of the shipyards stated that a current challenge in UHP blasting is that the nozzles in UHP blasting need to be very small to enable personnel to carry it out with hand-held devices. The robotic versions currently on the market, on the other hand, are not versatile enough to be applicable for the sometimes small vessels and limited surface areas to be blasted.

~~Can be used for the removal of rust and old layers of paint from floors and external sides. For hull fouling and the removal of loose paint, pressurised water blasting can be used.~~

~~Water blasting cannot be used on new surfaces, as it does not create a surface roughness in the material to be coated.~~

~~The use of ultra high pressure water blasting is not common practice in repair and maintenance, because there are some technical problems: it is reported that it is difficult to achieve spot blasting and more than 50 % of the areas to be blasted are ‘spots’.~~

~~This technique is also used in the preparation of yachts. When carried out in conjunction with recovery and separation of the wastes, it prevents the release of heavy metals and of TBT from old antifouling (note that the application of TBT on smaller yachts has been banned for more than 13 years).~~

### **Economics**

The disadvantage of UHP blasting is higher investment and maintenance costs compared to traditional methods (investment costs and maintenance costs are double or more than those of traditional methods). Some shipyards consider UHP blasting more economic than traditional techniques, some do not. Many case-dependent factors affect the overall costs, labour time, waste management costs, etc. In particular, waste management costs can be significantly higher in dry blasting than in UHP blasting. The amount of waste material to be disposed of can be one hundredth compared to dry blasting. The consumption of blasting media in traditional blasting can be 40–50 kg/m<sup>2</sup> while in UHP blasting only removed paint and rust are produced as solid waste, typically 0.5 kg/m<sup>2</sup>. Waste management costs can vary from tens of euros per tonne up to hundreds of euros per tonne depending on whether the waste can be recovered as material or needs to be disposed of as hazardous waste.

### **Driving force for implementation**

Legislation controlling dust emissions in the environment and health and safety in the workplace.

### **Example plants**

Widely used.

Den-Jet, Denmark and Hammelmann / Hammeli Oy, Finland,

### **Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005] [122, CEPE, 2006] [154, Nordic Council of Ministers, 2016]

#### 4.4.3.4 Induction coating stripping

##### **Description**

Moving an inductor head over the surface, causing localised fast heating of the steel to lift old coatings.

##### **Technical description**

An inductor head is moved over the steel surface, transferring high frequency electric currents to steel, creating a localised, controlled fast heating of the steel. This results in rapid disbanding of coatings up to 20-25mm. The induction head is mounted on an electrically driven semi-robotic platform.

##### **Achieved environmental benefits**

No dust emissions;  
Lower noise emissions;  
Reduced energy costs;  
Reduced waste quantities and the waste produced is more easily managed;  
Reduced water emissions, as waste is not finally divided and easily gathered without contacting water.

##### **Environmental performance and operational information**

The removed coating peels in strips with minimal production of dust and noise, reducing environmental emissions and the need for protective gear, particularly in closed environments such as tanks.

The system can operate on curved and vertical surfaces. It operates with higher stripping rates than blasting, lower energy costs. Less downtime and fewer operator hours.  
New coatings can often be applied directly to the cleaned surface with no further preparation.  
Other work such as maintenance and inspection can be carried out at the same time.

The system was developed for the cleaning and repainting of tanks, which is also carried out in for tankers in ship repair yards and is entirely compatible with cleaning

##### **Cross-media effects**

##### **Technical considerations relevant to applicability**

The system requires a minimum steel thickness of 5 mm to prevent damage to the backside coating or insulation materials.

##### **Economics**

No information provided.

##### **Driving force for implementation**

Speed of coating removal. Lower energy costs. Lower waste management costs.

##### **Example plants**

Removal of anti-skid deck coating, USS Nimitz.  
Oresund Drydocks, Landskrona, Sweden – (Repair Shipyards)  
Repsol Petronor Refinery, Bilbao.

##### **Reference literature**

[203. Gabe et al 2016]

#### 4.4.3.5 Other surface treatments

##### Description

Grinding is used on welded joints and other specific areas. Brushing may also be used, e.g. with wire brushes. Sanding is used between coats on yachts.

##### Achieved environmental benefits

No data submitted.

##### Cross-media effects

No data submitted.

##### Operational data

No data submitted.

##### Applicability

No data submitted.

##### Economics

No data submitted.

##### Driving force for implementation

Technical requirements.

##### Example plants

No data submitted.

##### Reference literature

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005] [122, CEPE, 2006]

#### 4.4.4 Coating materials

In general, the client usually specifies the coat systems to be used. The specification is also influenced by the warranty conditions of the coat. The yards have no influence on the coating system to be applied. especially in ship repair and maintenance and yacht building, repair and maintenance. The specification is also influenced by the warranty conditions of the paint.

##### **[Conventional solvent-based coating materials]**

**Description:** For the general description, see Section 0. On average, the conventional solvent-based paints applied onto ships contain 20–40 wt % organic solvent. The application is usually manually using airless spraying.

In repair yards for medium sized ships (>15000 GRT, with an average of 70000 GRT), the paints used contain on average about 30–40% organic solvents. About 150 g VOC are emitted per square metre painted, as the antifouling coats form the largest amount of paint applied. In Germany, it was reported that the paints used contain, on average, about 20–25 wt % organic solvents and about 100 g VOC are emitted per painted m<sup>2</sup>.

When applying solvent based systems, a VOC emission factor of about 100 to 150 g VOC/m<sup>2</sup> painted surface (without emission abatement) is reported.

Typically, processes in shipyards are carried out outdoors in dry docks, in open workshops or on the quay. Under these circumstances, VOCs from paints are emitted completely untreated.

**Achieved environmental benefits:** No data submitted.

**Cross-media effects:** No data submitted.

**Operational data:** Curing times are shorter than those required for water-based systems. It is common practice to treat the waste gases containing solvents.

**Applicability:** Solvent based paints can be used in all phases of the painting operations. For several applications, alternatives are available. However, the tie coat is always solvent based, and a solvent content of at least 270 g VOC/l is needed.

**Economics:** No data submitted.

**Driving forces for implementation:** Cost. Solvent based paints have been used for a long time and a lot of experience has built up.

**Example plants:** Widely used.

**Reference literature:** [13, DFU and IFARE, 2002] [11, InfoMil, 2003] [38, TWG, 2004] [78, TWG, 2005]

#### 4.4.4.1 Replacement of solvent-based materials (substitution)

##### 4.4.4.1.1 Water-based coats

###### Description

For a general description, see Section 17.7.2.2.

###### Achieved environmental benefits

Reduced VOC emissions.

###### Cross-media effects

Extra energy if forced ventilation or heating is applied.

###### Operational data

Longer drying times are required, although this can be shortened with good ventilation and, in some cases, heating. There are problems in ~~freezing and thawing conditions~~ application at low temperatures. Generally, the dry film thicknesses are lower on application.

###### Applicability

Water-based coats are available for some specific applications. Currently, water-based coats are the only viable alternatives to reduce VOCs in ~~internal areas and for ship primers~~. For internal areas solvent free paints are also available.

A water-based universal primer is widely used in Finnish yards for ship's internal areas. ~~Water-based paints are available for several applications, but are used only in limited numbers.~~ Solvent-based primer is only used in winter for outdoor application.

Water-based coats are not applicable on surfaces exposed to severe marine atmospheric conditions, e.g. heat, sun, rain and salt. The availability of water-based coats for ship and yacht manufacturing is as follows:

- Shop primers: water-based zinc silicate is available, but it is only sporadically applied. Water-based epoxy and modified alkyds are also available but not usually applied.
- Exterior of ships: water-based alkyd, epoxy and acrylate coats are available for yachts and occasionally applied. Water-based acrylate/alkyd and water-based zinc silicate are occasionally applied.

- Interior of ships: water-based systems are available, however, this poses difficulties in drying when applied in small and closed areas and are only occasionally applied. They are not applied in storage areas because they are not sufficiently wear-resistant.
- For yachts, water-based coats are available; they are now increasingly applied as primers and internal primers. The finish quality has limited their application in top coats.

Water-based antifoulings are also available, but only in the leisure craft sector ~~on the retail market~~.

### Economics

The costs involved for the water-based coat system for newly built ships are higher compared to solvent based paint systems. In the repair and maintenance of ships, incompatibility with old coat layers might require their removal by blasting, resulting in considerable costs.

### Driving force for implementation

~~IED~~.

### Example plants

Widely used in Finnish yards. Increasingly used for yachts.

### Reference literature

[11, InfoMil, 2003] [13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

#### 4.4.4.1.2 High-solid paints

##### Description

For the general description, see Section 17.7.2.1. The high solid-based coats currently applied contain 150 g VOC/l or more, ~~e.g. 450 g/l epoxies for underwater areas~~. Solvent-free 2 component coatings can also be applied on ships. These coatings form a very hard, pore-free and very smooth surface and are therefore very corrosion-resistant to seawater, oil products and chemicals. They are also resistant to abrasion, such as floating ice encountered during navigation. However, the product range that can be used is very limited.

##### Achieved environmental benefits

Reduced VOC emissions.

##### Cross-media effects

No data submitted.

##### Operational data

No data submitted.

##### Applicability

The applicability for ship and yacht manufacturing is as follows:

- Shop primers: high solids are not applied as the film thickness is ~~too~~ higher than required (only 20 µ required).
- Outside of ships and yachts for ~~the parts below~~ under water areas, external area, in holds and water tanks: high-solid epoxy coatings are widely applied. The VOC content of the coat applied on parts below the waterline is generally 450 g/l.
- ~~Outside of ships for the parts above the waterline: high solid epoxy coatings are applied; high solids flexible polyurethane coating is also applied. High solid alkyd coatings are not applied.~~
- ~~Inside~~ Internal areas of ships: high-solid epoxy ~~and alkyd~~ coatings are available.

- Yachts: high-solids coat may be used but generally they are not. They can be applied below the waterline. High solids are sometimes also applied on interiors.

~~Flexible surface tolerant high solids polyurethane coatings are partly replacing epoxy mastic/acrylic topcoat systems for new build and for maintenance purposes. They can be applied on almost any type of old paint.~~

~~Single and multilayered two component epoxy resin coatings are widely used. For example, in high wear areas of merchant ships, such as the whole external area, in holds and water tanks. These paints are also used for coating yachts.~~

#### **Economics**

The costs involved for the coat system for newly built ships are low. In the repair and maintenance of ships, incompatibility with old coat layers might require their removal by blasting, resulting in considerable costs.

#### **Driving force for implementation**

IED.

#### **Example plants**

Widely used.

#### **Reference literature**

[11, InfoMil, 2003] [13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

### **4.4.5 Additional corrosion protection – cathodic protection**

#### **Description**

In addition to protective coating systems the corrosion protection of the immersed surface of ships can be protected against corrosion by applying cathodic protection (e.g. impressed current or sacrificial anodes). It is also used in ships ballast tanks. Cathodic protection is an additional corrosion mechanism and does not replace coating systems.

#### **Achieved environmental benefits**

~~Cathodic protection is an additional corrosion mechanism and does not replace coatings systems. It may assist in increasing the periods between repair of the coatings and therefore to a reduction of the spraying activities and VOC emissions. Sacrificial anodes are not applied, so there is no emission of heavy metals.~~

#### **Cross-media effects**

No data submitted.

#### **Operational data**

~~Neighbouring ships in the harbour that are slightly damaged may experience accelerated corrosion.~~

No data submitted

#### **Applicability**

Used worldwide on all kind of ships, both for professional and (less commonly) recreational use.

#### **Economics**

No data submitted.

#### **Driving force for implementation**

No data submitted.

### Example plants

Widely used.

### Reference literature

[11, InfoMil, 2003] [38, TWG, 2004] [78, TWG, 2005].

## 4.4.6 Coat application techniques and equipment

### ~~[Airless spraying]~~

~~For a general description, see Section 0. For the construction and maintenance of all new ships, almost all paint layers are commonly applied with airless spraying. The amount of overspray is about 30 % maximum of the material input.~~

~~[13, DFIU and IFARE, 2002] [11, InfoMil, 2003] [78, TWG, 2005]~~

### 4.4.6.1 Hot spraying

#### Description

For a general description, see Section . On ships, hot airless spray is used to apply solvent-free two-component coatings ~~can be applied by using hot airless spraying~~. Layers of 300–1000 microns are achieved.

#### Achieved environmental benefits

VOC emissions are ~~omitted~~ highly reduced and, compared to conventional airless spraying (see Section 17.7.3.15), the number of layers can be reduced.

#### Cross-media effects

Energy is used for heating.

#### Operational data

Computerised on-site mixing is required to achieve the proper mixing ratio. Working time is short with a pot-life of only 10 minutes. ~~These types of coatings form a very hard, pore free and very smooth surface and are therefore very corrosion resistant to seawater, oil products and chemicals. They are also resistant to abrasion, such as floating ice encountered during navigation. However, the finish may poor, and the product range that can be used is very limited.~~The equipment used for hot spraying is difficult to repair.

#### Applicability

This technique can be applicable for the coating of large surfaces on the interior and exterior of the ship.

#### Economics

The costs for these coatings are higher compared to conventional coatings, however, labour time is shorter and so is the drying time. ~~Savings are there because less energy is used for spraying activities and costs for maintenance are reduced.~~ The equipment costs for hot spraying are higher.

#### Driving force for implementation

IED.

### Example plants

No data submitted.

### Reference literature

[11, InfoMil, 2003] [78, TWG, 2005]



#### 4.4.6.2 Integrated air extraction at the point of application

##### Description

A mobile coat application head with an integrated overspray extraction system has been developed which extracts air at the point of spraying. This is analogous to robot spraying (see Section 4.2.3).

The technique is reported to be no longer used but research is done to further develop these techniques and equipment.

##### Achieved environmental benefits

Due to the increased efficiency, the material consumption, the VOC emissions and also the overspray emissions are significantly reduced. Overspray can be reduced to 5 % of the material input.

##### Cross-media effects

No data submitted.

##### Operational data

No data submitted.

##### Applicability

These coat application units can only be used for even, perpendicular surfaces, and not, for example, on curved bow and stern sections or flat bottoms.

##### Economics

No data submitted.

##### Driving force for implementation

Health and safety.

##### Example plants

Blohm + Voss GmbH, Hamburg, Germany. HDW Kiel, Germany

##### Reference literature

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

#### 4.4.7 Alternatives to antifouling paints based on biocides

For information on the environmental impacts of using antifouling coats based on biocides, see Section 4.2.3.

##### 4.4.7.1 Fouling release coatings based on silicones

##### Description

Silicone coats have a low surface tension (non-stick) with the effect that the fouling organism cannot establish a firm attachment to the coating surface. Fouling may attach to the surface during idle periods, but currents created over the paint surface during sailing faster than a certain minimum speed will clean the surface. Silicone paints are applied by airless spraying.

##### Achieved environmental effects

Foul-release coatings do not contain any biocides. They provide very smooth surfaces resulting in a potential for lower frictional resistance. This may decrease fuel consumption or increase speed compared to self-polishing biocide containing paints.

Foul-release coatings do not erode or polish during service time and as such the paint is kept intact during the service period.

### **Cross-media effects**

No data submitted.

### **Operational data**

During application of silicone coatings, overspray to surfaces to be coated with other types of paint must be prevented due to later adherence problems. Application and repair of silicone paints need to be done strictly according to a specified procedure.

### **Applicability**

Fouling organisms will be able to settle on the silicone paints during idle periods. In order for the release effect to work during the sailing period, a certain speed has to be achieved. Today, the technology can be used on ships with short idle periods and a minimum speed of 15–17 knots. Silicone paints are not suited to vessels exposed to a lot of mechanical damage. Therefore foul-release coatings are still considered to be niche products for special vessel types.

### **Economics**

Costs of silicone paints are considerably higher compared to antifouling paints containing biocide.

### **Driving force for implementation**

IED. Water pollution legislation and policies.

### **Example plants**

Used worldwide.

### **Reference literature**

[78, TWG, 2005]

## **4.4.7.2 Hard, smooth coating with frequent mechanical cleaning**

### **Mechanical methods**

#### **Description**

Anti-fouling coatings may be replaced by the use of hard, resistant coating materials reducing fouling adhesion and brushing and scraping off fouling at short intervals.

Brushing and scraping off fouling in short intervals and the use of hard, resistant coating materials is an alternative to antifouling coats. There is a variety of devices with rotary brushes which can remove the fouling during short downtimes.

#### **Achieved environmental benefits**

This antifouling method does not use heavy metals or biocides.

#### **Cross-media effects**

This method does not reduce the risk of the introduction of new species from the world seas.

Underwater brushing creates an uncontrolled risk of water pollution during such diving operations.

#### **Operational data**

The disadvantages of the procedure are short cleaning intervals.

#### **Applicability**

This process is suitable for ships operating in brackish or fresh water at lower temperatures.

**Economics**

No data submitted.

**Driving force for implementation**

IED. Water pollution legislation and policies.

**Example Plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [69, Watermann, et al., 2003] [78, TWG, 2005]

**4.4.7.3 Electrochemical processes****Description**

Anti-fouling coatings may be replaced by applying a voltage potential at the vessel surface. This causes electrolysis. Fouling is inhibited by toxic chlorine compounds produced at the surface (in salt water) and/or the pH value at the surface is shifted which inhibits the settling of fouling. This technique abates corrosion

~~The surface is protected by voltage, which causes electrolysis. Toxic chlorine compounds are produced (in salt water) and/or the pH value at the surface is shifted which inhibits the settling of fouling. This technique abates corrosion.~~

**Achieved environmental benefits**

This antifouling system does not contain biocides.

**Cross-media effects**

The electrodes can be made of copper, resulting in the emissions of copper ions which are toxic to the fouling organisms. Toxic chlorine compounds are produced.

**Operational data**

The amounts of copper released are comparable to copper-based antifoulings. This method proved to be very effective against fouling.

**Applicability**

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

IED. Water pollution legislation and policies.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [69, Watermann, et al., 2003] [78, TWG, 2005]

**4.4.8 Waste gas treatment****Description**

For a general description, see Section 17.10.

Emissions from painting and blasting activities can be reduced effectively by using closed workshops (see Sections 4.4.2.2 and 17.10.2.1). These can be equipped with waste gas treatment techniques as described in Section 17.10.

For example, VOC-containing waste gases from spraying can be adsorbed via activated carbon (see Section 17.10.6.3). Alternatively, the organic solvents can be treated in a thermal oxidiser (see Section 17.10.5.4). Where concentrations of VOCs allow, the solvent can be regenerated from absorption, or the thermal oxidiser used can be regenerative and recover the heat from the oxidation process.

Dust and overspray particles may be treated by techniques described in Section 17.10.2.9.

### **Achieved environmental benefits**

Significant reduction in VOC and/or dust emissions.

At the example plant, a waste gas treatment installation of 300 000 m<sup>3</sup>/h capacity is used. VOC emissions are reduced by 75 % and an average clean gas concentration of 23 mg/m<sup>3</sup> is achieved. Efficient ventilation and dust abatement systems enable a five-fold change of air each hour and in the cleaned air, dust concentrations of less than 5 mg/m<sup>3</sup> can be achieved.

### **Cross-media effects**

Energy consumption for waste gas treatment.

### **Operational data**

Dust levels may have to be reduced prior to VOC abatement.

### **Applicability**

Applicable to the refurbishment of shipyards.

### **Economics**

High costs are involved.

The investment for the example plant was about EUR 21 million. The annual operation costs are about EUR 1 million, which is slightly lower than the operational costs for the conventional process. This also included filter systems for grit blasting operations.

### **Driving force for implementation**

IED.

### **Example plants**

HDW Kiel, Germany.

### **Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

## **4.4.9 Waste and waste water management**

### **4.4.9.1 Segregation of waste and waste water streams**

#### **Description**

Docks and slipways are constructed with:

- a system to collect and handle dry waste effectively and keep it separate from wet waste;
- a system to separate waste water from storm water and run-off water.

#### **Technical description**

No information provided

**Achieved environmental benefits**

Reduces water pollution.

Facilitates waste handling, storage and subsequent management.

**Environmental performance and operational information**

No information provided

**Cross-media effects**

No information provided

**Technical considerations relevant to applicability**

As this involves construction work, only applicable to new docks and slipways or major upgrades of existing ones.

**Economics**

No information provided

**Driving force for implementation**

No information provided

**Example plants**

Widely applied

**Reference literature**

[151, CESA 2011]

**4.4.9.2 Waste water treatment****Description**

Use of appropriate waste water treatment (WWT) systems that are able to effectively remove various pollutants from waste water, e.g. oil, grease, paint residues potentially containing heavy metals and biocides

**Technical description**

Waste water can be treated prior to discharge, either at the source (e.g. when slurry blasting) or collected and sent to a waste water treatment plant, either on or off-site. The treatment required will depend on the substances present and the discharge point (to surface waters such as the harbour, or to the municipal foul sewer). Section 17.11 discusses several waste water treatment techniques and provides other sources of information.

**Achieved environmental benefits**

Reduction in water pollution, particularly in enclosed harbours or estuarial areas.

**Cross-media effects**

Any energy and chemicals used in treatment.

**Operational data**

For example:

(i) When using water blasting techniques, the waste water can be collected in the dock, put into tanks and fed into waste water treatment plants (see Section 4.3.2.2).

(ii) At one installation, the waste water treatment is in several steps consisting of precipitation and flocculation (such as by using iron (III) chloride), followed by separation and filtration. To reduce the volume and weight of waste produced, the separated sludge is pressed prior to disposal. The cleaned waste water is reused or, in the case of surplus water, discharged as waste

water. With this system, emission levels for filterable substances of 10 mg/l can be achieved after treatment.

### **Applicability**

Generally applicable

### **Economics**

Costs are dependent on the size of the installation. In example (ii) given above, the cost in Germany for the complete plant including installation was about EUR 100 000 (in 2000).

Costs for water treatment installations in ship repair yards dealing with medium sized ships (> 15 000 GRT) are quoted as exceeding EUR 2 million.

### **Driving force for implementation**

Water, port and harbour pollution legislation.

### **Example plants**

Flender-Werfft, Lückbeck, Germany.

### **Reference literature**

[13, DFIU and IFARE, 2002] [78, TWG, 2005]

## **4.4.9.3 Waste management and minimisation**

### **Description**

As part of the dock discipline (see Section 4.4.1), manage waste by:

- minimising; recovering, reusing and recycling (particularly dry blasting grit);
- Storing wastes safely in designated, labelled containers in covered areas.

### **Technical description**

The following residues are collected and their disposal is managed according to the relevant legislation and procedures. This is particularly important prior to flooding a dry dock:

- paint residues that have been removed;
- paint leftovers, and used paint recipients;
- coating overspray;
- used and contaminated blasting abrasives;
- cleaning materials;
- mud, oily residues and other materials that have been scraped off or removed.

Some materials, such as used abrasives (particularly dry blasting grit) and scrap materials, may be collected separately to assist their recycling and reuse.

### **Achieved environmental benefits**

Prevention of contamination of the water environment.

### **Cross-media effects**

None.

### **Operational data**

See dry dock discipline, Section 4.4.1.

### **Applicability**

Generally applicable in all cases.

**Economics**

Cost reduction in reusing materials (especially dry blasting grit).  
Cost recovery in recycling scrap materials.

**Driving force for implementation**

Meeting water pollution, port waste and harbour waste management regulations.

**Example plants**

Widely practised.

**Reference literature**

[78, TWG, 2005] [121, Portugal, 2006].

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## 5 COATING OF AIRCRAFT

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

### 5.1 General information on the coating of aircraft

[176, ASD 2017]

In this section, the painting of civil aircraft ~~with more than 50 seats~~ is described. Due to different processes, this section is divided into construction and maintenance.

For maintenance, the paintwork is repaired or applied completely new, and the entire paint application is carried out manually. The selection of the coating system depends on manufacturer defaults, international regulations and requests of the customer. ~~Data reported in this section on aircraft maintenance were gathered at the Lufthansa Technik AG, located in Hamburg, Germany.~~

~~Applied processes and techniques for new constructions were investigated at AIRBUS Deutschland GmbH in Hamburg, Germany.~~

~~AIRBUS is the only large civil aircraft constructor in the EU 25, but other companies build smaller aircraft, military aircraft or fabricate sections (such as wing sections). The main carriers also have maintenance facilities which may carry out coating. There are also other commercial maintenance facilities in some countries as well as military facilities which may carry out coating. As the coating for whole aircraft, fuselages and large sections is carried out by hand on a batch basis, the rate of consumption of solvent per hour may be more pertinent than the annual quantity consumed [138, Humberstone. S].~~

## 5.2 Applied processes and techniques in the coating of aircraft

[176, ASD 2017]

### 5.2.1 Construction

Aircraft need to be protected against corrosion for their entire life of around 25 years, therefore only specific paint systems can be utilised, as with the maintenance of aircraft, whilst also taking customer requests into consideration

#### 5.2.1.1 Painting of components and detailed parts – structural coating

~~Components are partly painted before assembly takes place. These component parts are coated with a primer and subsequently with a topcoat. A wash primer is only applied in exceptional cases. Increasingly surface spraying is automated. Convection driers and also infrared driers are used for the painting of components. The surface area of the components is about four times greater than that of the aircraft's exterior surfaces. Parts that are delivered by external manufacturers are already coated with ground coats containing chromate.~~

Components are mostly partially painted before assembly takes place. These parts are coated with a primer (containing chromates in the case of metallic parts, chromate-free in the case of composite parts) and may be subsequently painted with a topcoat or varnish. A wash primer is only applied in exceptional cases, i.e. touch-up and repair. Where production processes allow sufficient throughput surface, spraying is sometimes automated. Convection dryers and also infrared dryers are used for accelerated drying of components either in a flow process or by the use of combination painting and drying booths. Parts that are delivered by external manufacturers are normally supplied coated with a basic primer and topcoat if requested (in the case of aluminium parts the basic primer contains chromates, but chromate-free primer is used for composite components).

Chromates have been used for over 50 years as a corrosion inhibitor in the protection of metallic surfaces, fulfilling the demanding technical, safety and airworthiness requirements of the aerospace and defence sector. With the use of chromates, corrosion protection can be afforded for lengthy periods, thus providing high levels of anti-corrosion reliability in products with long life cycles, even in extreme conditions.

In some very specific cases, e.g. structural applications on certain materials (composite, titanium), a non-inhibited primer can be used.

However, despite intensive research efforts carried out over the past decades by the sector, there are currently no chromate-free alternatives available for some specific processes in the aerospace and defence sector fulfilling the required level of performance, reliability and safety. The process for the aerospace and defence industry in terms of qualification and certification of alternatives has been reflected in an EASA/ECHA report<sup>20</sup> which has been drawn up jointly with industry.

In the frame of the REACH regulation, applications for authorisation to continue using some chromates in applications such as paints, primers, surface treatment and hard chrome, for which no suitable alternatives will be available for implementation before the respective ban dates (2017 and 2019), have been made to the European Chemicals Agency. These collective Applications have been prepared in the frame of industry consortia with main actors from the aerospace and defence sector and the chemical industry.

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<sup>20</sup> An outline of key aspects of the authorisation process in the context of the aviation industry, EASA-ECHA, April 2014.

### 5.2.1.2 Painting of exterior surfaces

Outside surfaces of the completed aircraft are coated manually. As the final lacquer finish takes place after the first flight, only coatings that cure at an ambient temperature can be used. At present, predominantly solvent-based paints (with solvent contents of about 55–65 %) are used. However, high solid paints (with a solvent portion of between 30 and 40 %) are increasingly used. As with maintenance, the coating of new planes is carried out in closed workshops. The applied coatings cure at ambient temperatures. First, the hull is coated and completely dried. Then, the hull is masked with packaging paper and the wings are subsequently painted. The paint layers are applied by the wet on wet technique. The painting process is subdivided in pretreatment, application of the wash primer, application of the primer and application of the topcoat.

Outside surfaces of the completed aircraft are coated manually. As the final lacquer finish is applied after the final assembly of the aircraft, only coatings that cure at an ambient temperature can be used. At present, predominantly high-solid paints (with a solvent portion of between 30 % and 40 %) are used, and this is standard in the aeronautical industry. However, conventional solvent-based paints (with solvent contents of about 55–65 %) might still be used by companies producing small and/or military aircraft.

As with maintenance, the coating of new planes is carried out in closed workshops. The applied coatings cure at ambient temperatures. Often the hull is coated and completely dried first. Then, the hull is covered with masking materials and the wings and tailplane are subsequently painted.

#### 5.2.1.2.1 Conventional paint scheme

The painting process is subdivided into application of the wash primer, application of the primer and application of the topcoat.

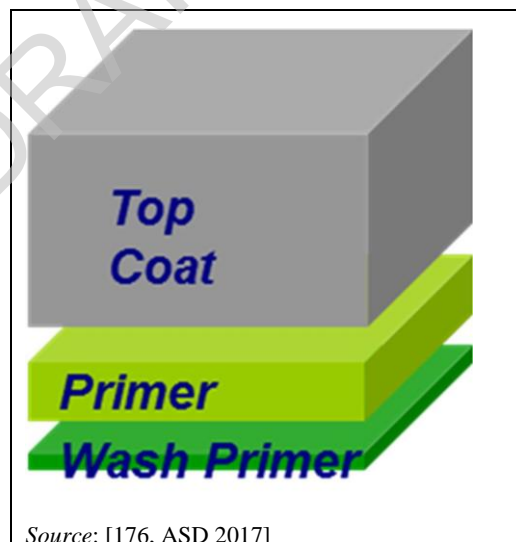


Figure 5.1: Conventional paint scheme

### **Pretreatment**

~~Before the exterior surfaces are coated, impurities, e.g. kerosene, oils and grease, are removed. The hull is cleaned with cleaning agents and the total consumption per aircraft amounts to about 200 litres. Afterwards, anodisation with chromic acid takes place. The purpose is to generate a thicker oxide layer for increased corrosion protection. The primer containing chromate is sanded dry and the hull is again cleaned with organic solvents.~~

Before the exterior surfaces are coated, impurities, e.g. kerosene, oils and grease, are removed. The hull, wings and tailplane are cleaned with cleaning agents. The surfaces are sanded and then cleaned again.

### **Application of the wash primer**

After pretreatment, the wash primer is applied manually by using electrostatic spraying techniques. The wash primer is a solvent and chromate containing material based on polyurethane or epoxy resins or polyvinyl butyrate (PVB). The solvent content amounts to about 70–90 %. For increased corrosion protection, strontium or zinc chromate is necessary. The layer thickness varies from 8–10  $\mu\text{m}$ . After application, evaporation of solvents takes place at ambient temperature.

### **Application of the primer**

After the wash primer, a solvent containing primer based on epoxy resin or polyurethane is applied. This is done manually via an electrostatic spray application. The solvent content of these materials varies from 50–65 %. The content of strontium or zinc chromate amounts 10–20 %. The applied layer thickness averages 15–25  $\mu\text{m}$ . The material cures at ambient temperature.

### **Application of the topcoat**

The topcoat can be very different according to customers' requests. Solvent-based two-component paints with a solvent content of 55–65 % are exclusively used. The topcoat is applied in several layers (two to four according to the colour) via electrostatic spraying. According to the applied colour, the layer thickness amounts to 60–100  $\mu\text{m}$ . ~~After the first layer is applied, a short flashing off takes place and, before a second layer is applied, another evaporation of about one hour takes place. Subsequently, the three layers are dried. Afterwards, the decoration is applied via a spray application or by pressure sensitive foils. For the painting of exterior surfaces, conventional paints and high solid paints with a solid content of about 70 % can be used. At the request of a customer, a clear coat can be applied on the topcoat.~~ When the first layer has been applied, a technical waiting time must be respected before the next layer can then be applied during a limited over-coating time window. This is repeated until the required number of layers has been reached. Subsequently, the topcoat layers are dried. Afterwards, the decoration colours are applied either via a number of topcoat spray applications for each colour or by decorative adhesive films. At the request of a customer, a clear coat can be applied on top of the topcoat.

#### **5.2.1.2.2 12.2.1.2.2 High-solid paint scheme**

The current standard external paint system consists of a high-solid chrome-free epoxy primer and a high-solid polyurethane topcoat applied on top of the basic protection of the detailed parts (see 0). High-solid base coat and clear coat combinations are increasingly used instead of the topcoat. A wash primer is no longer used. The customer can select an option, which consists of applying a solvent-based intermediate coat between the high-solid chrome-free epoxy primer and the topcoat (or the base coat), in order to improve the strippability of the paint system for a later maintenance repaint.

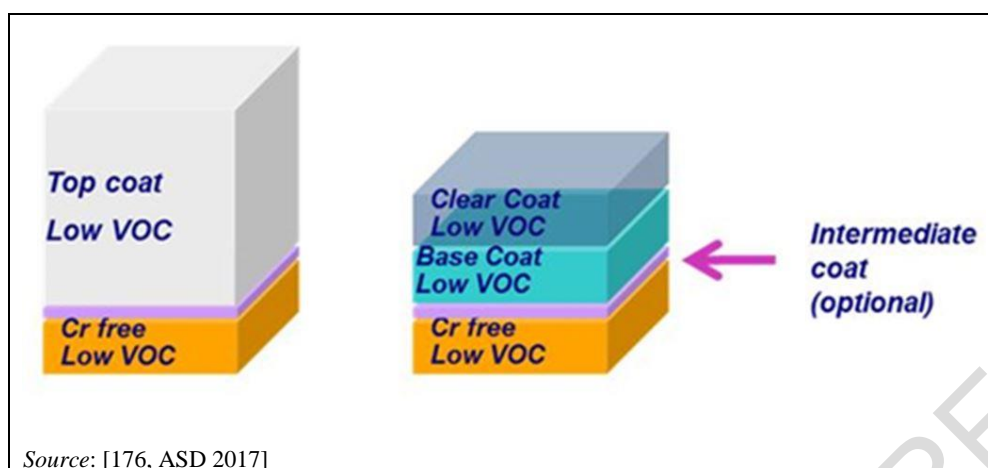


Figure 5.2: High-solid paint scheme

### 5.2.1.3 Temporary corrosion protection

The so-called ‘temporary corrosion protection’ is obtained by application of water-rejecting layers in the internal area of the aircraft. The material remains in the plane permanently. The main areas are, for example, doors, gates, wheel wells and cargo storage areas and any locations where high corrosion risks or condensation may occur. Temporary corrosion protection is not applied within fuel tank boundaries. The temporary corrosion protection materials are solvent-based, wax-like substances. The application takes place with a brush or via spraying. The solvent content of the products amounts to about 40 - 60 %. ~~About 60—80 litres are processed per aircraft.~~

## 5.2.2 Maintenance

The paint application is carried out in closed workshops where temperature and air humidity can be regulated. For the deposition of overspray from exhaust air streams, wet dust collectors are installed. The applied paints dry at ambient temperature.

### 5.2.2.1 Paint removal

In the context of maintenance, the primary coat and the topcoats are removed every six to eight years. If an airline company changeover takes place, paint removal is undertaken sooner. This is most common for leasing companies. The paint removal (and new paint application) is done for optical reasons and for examining the structure for wear and corrosion. Paint removal is usually done chemically. Water blasting, which was favoured for environmental reasons, is no longer applied due to the causation of excessive mechanical stress. The aircraft is cleaned with a water-based, alkaline cleaning agent. After drying the windows, running gear and parts consisting of fibre-reinforced plastic, composite materials are masked. The following paint removal process is done via acid cleaning or by mechanical sanding. For acid cleaning, a water-based benzyl alcohol formic-acid is applied with airless spraying techniques. The sealants in the seams are manually removed. For composite materials and partly for metal surfaces, pretreatment is done by sanding.

### 5.2.2.2 Cleaning

Macerated paint layers are removed by water. Subsequently aqueous-alkaline neutralisation and cleaning takes place. Before paint application, the surfaces are cleaned manually with organic

solvents and cleaning wipes. In general, a mix of butyl acetate and butyl alcohol is used as solvent.

### 5.2.2.3 Pretreatment

Before the primer is applied, a solvent-based wash primer is applied onto metal surfaces. This material contains 76 % organic solvents and about 14 % zinc chromate (in the solid content). Up until now, no zinc-free materials have been used. The material is applied via an electrostatic spray application. The wash primer is not applied onto composite materials.

### 5.2.2.4 Primer

Two different materials are used as primers:

- primer based on polyurethane or epoxy with a solvents content of 70 % without chromate; and
- primer with strontium chromate (about 20 % of the solids content) and about 67 % organic solvents.

Primers containing chromate are used for increased corrosion protection for climate conditions with a high humidity and high salinity of the atmosphere or upon the request of a customer. Application is carried out manually via electrostatically assisted spray applications.

### 5.2.2.5 Topcoat

As topcoats, conventional two-component paints with a solvent content of about 61 % and three-component high-solids with a solvent content of about 43 % are used. Both paints are free of chromate and lead. The application is carried out manually by electrostatically assisted spraying.

### 5.2.2.6 Clear coat

Conventional topcoats are generally coated with a clear coat layer. If high-solid topcoats are applied, an additional clear coat layer is not necessary. It is only used at the request of a customer. The same application method as for topcoats is used.

### 5.3 Current consumption and emission levels in the coating of aircraft

[13, DFIU and IFARE, 2002] [155, TWG 2016]

#### 5.3.1 Construction

##### 5.3.1.1 Material consumption

For the determination of the material consumption, the aircraft's surface has to be measured. In addition to the exterior surface, the surface of coated component parts also has to be taken into account. Coating the exterior surface takes up to eight days. Most of the time is needed for masking and finishing. The largest amount of paint is consumed by the coating of component parts. The surface area of component parts is about four times greater than that of the exterior surface of the completed aircraft. Table 5.1 shows material consumption for an Airbus A320 (150 passenger seats).

**Table 5.1: Coated surfaces for an Airbus A320**

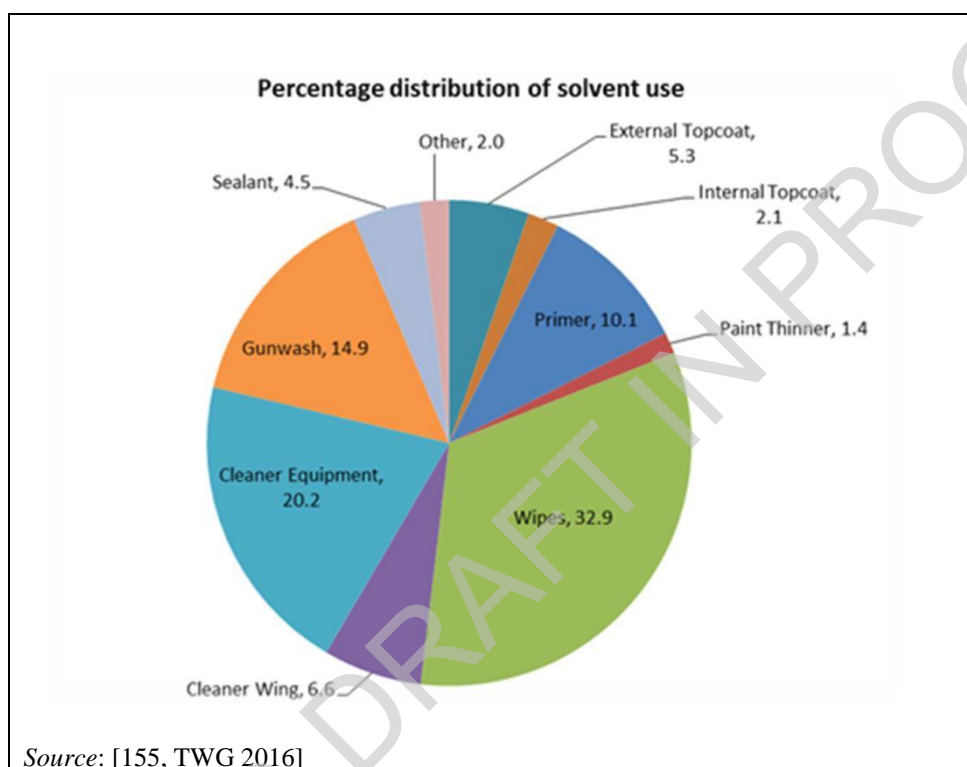
Coating surface	Surface (m <sup>2</sup> )	Layers
Component parts	3 600	1–2
Outside surfaces	1 200	2–4
Inside area	500	2
Conservation of rivet heads	10 000 (running metres)	1–2
<i>Source: [13, DFIU and IFARE, 2002]</i>		

For the coating of an Airbus A321 (about 180 passengers), the total surface area of components and interior areas is about 3 600 m<sup>2</sup> and the total exterior surface area of the completed aircraft is about 945 m<sup>2</sup>. The applied dry material has a total weight of 380 kg. For an average paint system (consisting of wash primer, primer and topcoat), about 0.9 kg/m<sup>2</sup> material is applied. For the painting of component parts or single paint layers, no data could be obtained. Data of the paint consumption are given in Table 5.2.

**Table 5.2: Consumption of materials for the painting of exterior surfaces of planes**

Paint layer or process step	Material consumption
Pretreatment	200 l solvents (30 % isobutanol and 70 % butyl acetate) for 600 m <sup>2</sup>
Wash primer	75 kg wet lacquer (for the hull); overspray about 20 %
Primer	100 kg wet lacquer (for the hull); overspray about 20 %
Topcoat	200 kg wet lacquer (for the hull)
<i>Source: [13, DFIU and IFARE, 2002]</i>	

The percentage distribution of solvent use per process at one installation is presented in Figure 5.3. It is worth noting that cleaning activities represent about 75 % of total solvent use (product cleaning: ~ 40 % and equipment cleaning about 35 %). [155, TWG, 2016, #077].

**Figure 5.3: Percentage distribution of solvent use per process for one installation**

### 5.3.1.2 Water consumption

No data submitted.

Water consumption data were reported by two installations: the first with a total consumption of the order of 6 600 m<sup>3</sup>/yr with the major consuming sector being the wet scrubbers for VOC emission abatement. The second reported figure was 41 700 m<sup>3</sup>/yr.

### 5.3.1.3 Energy consumption

No data submitted.

No detailed data on energy consumption were submitted, to allow estimation of any type of specific energy consumption.

In general, total energy consumption is of the order of tens of thousands of MWh and energy metering is performed.



The main identified techniques for decreasing energy consumption and improving the energy efficiency are:

- exhaust air heat exchanger in ventilation systems of all hangars with estimated energy savings of the order of 20–30 %;
- air recirculation of booth air during preparation, flash-off and curing processes;
- temperature and humidity optimisation of the process air with estimated energy saving of the order of 15 % (gas consumption);
- optimisation of energy consumption for the warm air circulation for curing, e.g. by using air turbulator.

### 5.3.2 Emissions

[78, TWG, 2005] [155, TWG 2016]

About 600 g VOC/m<sup>2</sup> are emitted for an average material consumption of about 0.9 kg/m<sup>2</sup>. The emitted overspray is far below 1 mg/m<sup>3</sup>. The total VOC emissions per aircraft amount to 450 kg for the painting of exterior surfaces. For a plant with a production capacity of 60 aircraft per year, approximately 27 t of VOC are emitted from the coating of exterior surfaces.

Since the interior surface area is about four times greater than that of the exterior surface area, the entire emission for the plant can be estimated up to about 100 t per year. The painting of component parts is generally carried out in different plant locations. In the Airbus Deutschland GmbH Company in Nordenhamm, Germany, the total solvent input was about 131 t in the year 2000. In the Airbus plant in Hamburg, Germany, 69 t VOC/yr may be processed, according to their permit. In 2001, 70 aircraft were produced there.

~~Due to the difficulty of enclosing the large items being coated (whole planes, fuselages, wings and other large sections) and the high air volumes subsequently extracted. Therefore, a key technique to reduce VOC emissions is to reduce the amount of VOC in the coatings used, for example, by using high-solids and/or two-component coatings.~~

#### 5.3.2.1.1 Total VOC emissions

On average, the total VOC emissions per kg of solid input are of the order of 0.55–0.6 kg.

The relevant total VOC emissions expressed as a percentage of the total solvent input are presented in Table 5.4.

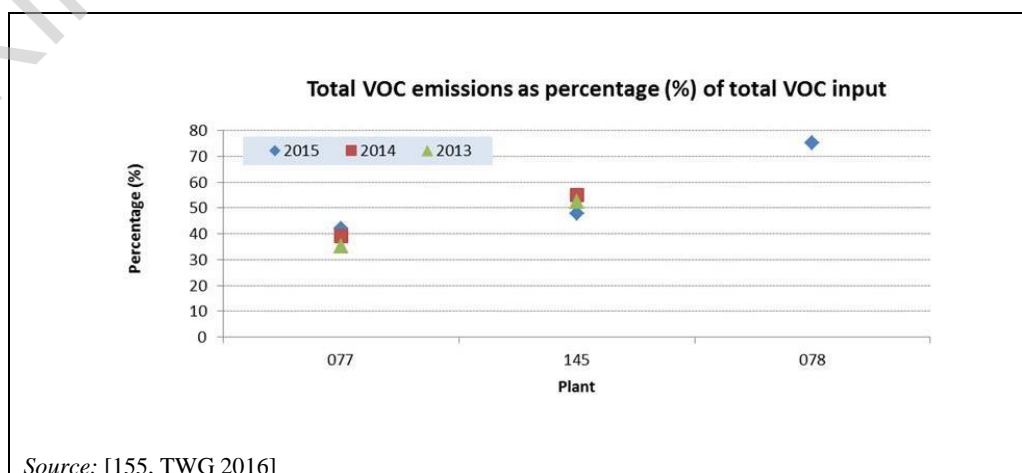


Figure 5.4: Reported values of total VOC emissions expressed as a percentage of the total solvent input

5.3.2.1.2 Fugitive VOC emissions

Reported data on solvent mass balances from three installations show that fugitive emissions vary from less than 10 % up to 50 % of the total solvent input (see Figure 5.5)

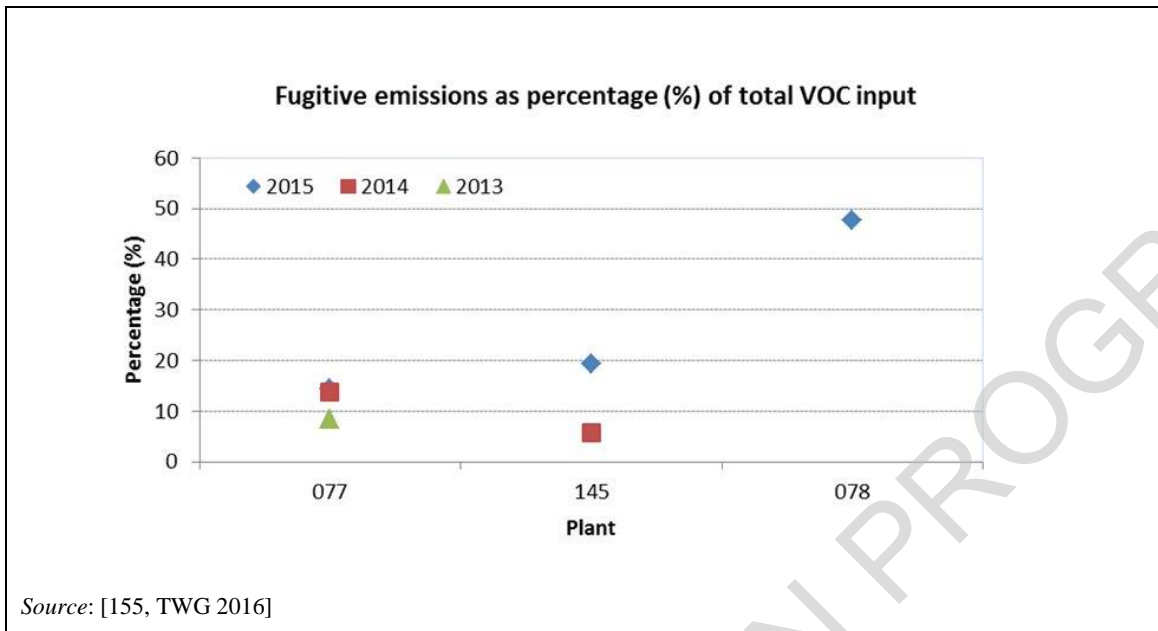
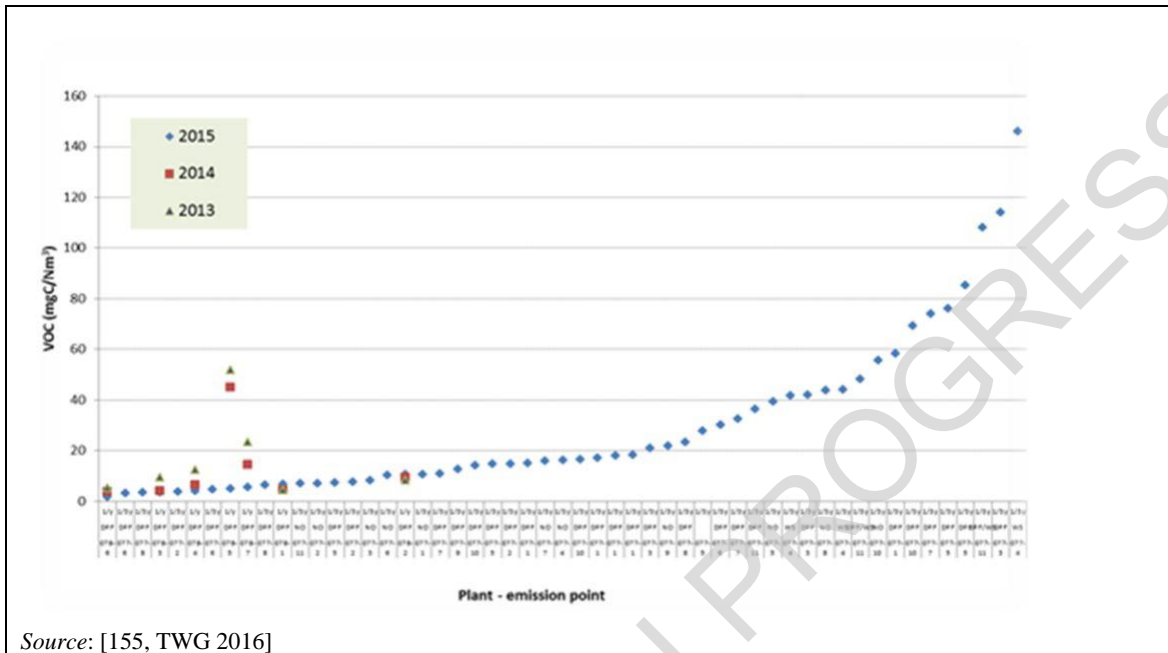


Figure 5.5: Fugitive emissions as a percentage of the total solvent input (I) for three aircraft coating installations

### 5.3.2.1.3 VOC emissions to air in waste gases

Reported values for periodic monitoring of VOC emissions are presented in Figure 5.6.

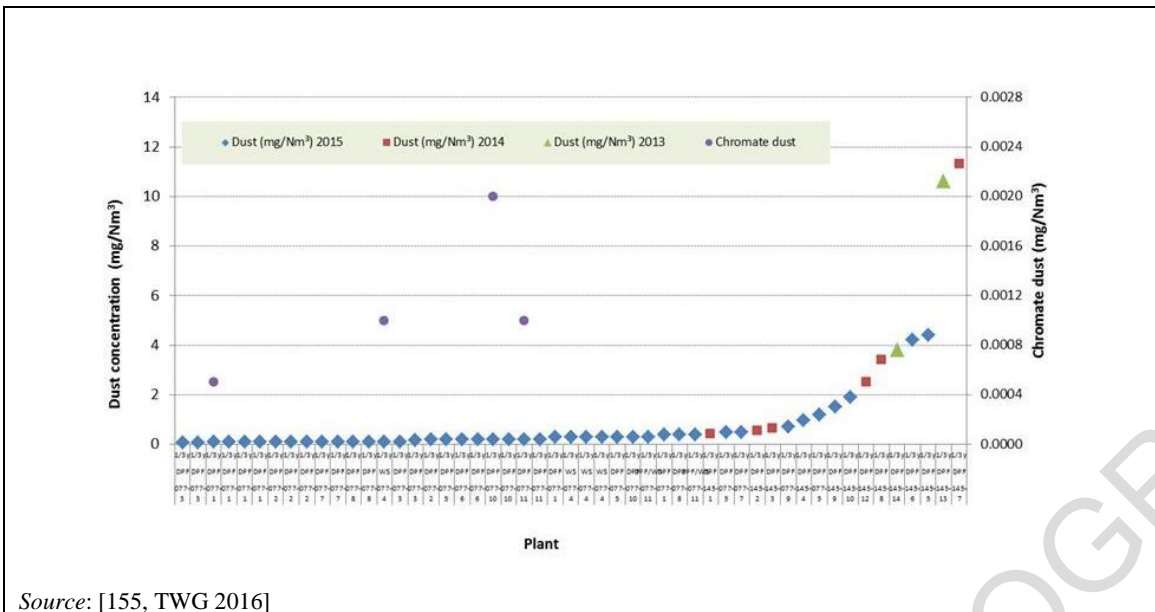


**Figure 5.6: VOC emissions to air in waste gases expressed as mg C/Nm<sup>3</sup> for periodic monitoring for the period 2013–2015**

Although the applied abatement techniques focus mainly on dust abatement, the reported VOC concentration values are generally low. It should be noted that the reported waste gas flow rates vary from 20 000 Nm<sup>3</sup>/h up to 180 000 Nm<sup>3</sup>/h.

### 5.3.2.1.4 Dust emissions to air in waste gases

Total dust and chromate dust emission data reported from the reference installations are presented in Figure 5.7. In general, the achieved dust emission concentration values are below 3 mg/Nm<sup>3</sup> and chromate dust values are lower than 0.002 mg/Nm<sup>3</sup>.



Source: [155, TWG 2016]

**Figure 5.7:** Dust and chromate dust measured concentration values expressed in mg/Nm<sup>3</sup> for periodic monitoring in 2015

The basic statistical parameters of the reported dust concentration values for 2015 are presented in Table 5.3.

**Table 5.3:** Statistical parameters of reported dust concentration values in 2015

No of points	Average	Median	25 <sup>th</sup> percentile	75 <sup>th</sup> percentile
43	0.52	0.20	0.10	0.40

Source: [155, TWG 2016]

### 5.3.2.2 Emissions to water

Along with the paint sludge, waste water is generated from the wet deposition of overspray. The treatment of waste water is similar to the processes used in the serial painting of passenger cars.

Data on emissions to water were only submitted for one plant (out of the three participating in the data collection) and with only one value for hexavalent chromium.

### 5.3.2.3 Waste

The following table summarises the main types of waste and the quantities of waste generated in the coating of aircraft.

Table 5.4: Waste generation data from the coating of aircraft

Waste type / description	Source/origin	Quantity (t/y)	Average solvent content (%)	Recycling or disposal route
Solvent leftovers	Production processes	30–60	100	Delivered off site
Paint sludge	Production processes	20–30	30–55	Delivered off site
Waste solvent	Cleaning processes	2–3	75–100	Delivered off site
Waste base coat	Production processes	5–30	30–40	Delivered off site
Waste hardener	Production processes	5–20	50	Delivered off site
Paint filters	Production processes	30–50	0	Delivered off site
Empty paint containers	Production processes	NI	NI	Delivered off site

Source: 155, TWG 2016

- ~~paint sludge~~
- ~~filters~~
- ~~cleaning wipes~~
- ~~organic solvents (recycled)~~
- ~~packaging paper (recycled)~~
- ~~foils~~
- ~~grinding dust~~
- ~~empty paint containers.~~

The proposed techniques for the minimisation of generated waste are as follows:

- use of reusable containers to reduce the amount of scrap metal;
- recovery of used solvent from the gun cleaning which in the case of the reporting plant is done by external contactor;
- recovery of used solvents by distillation (for one plant the estimated initial recovery rate was 60 vol-% with a declining trend over time);
- dewatering of sludge from the waste water treatment facility using centrifuges and decanters.

### 5.3.3 Maintenance

Due to different geometries of aircraft, the consumption and emission values are given for a Boeing 747-400 (see Table 5.5). For this type of aircraft, about 2 780 m<sup>2</sup> has to be painted. The data come from Lufthansa Technik, Germany from 2001.

Table 5.5: Material consumption for a Boeing 747-400 at Lufthansa Technik

Process	Material	Material consumption (kg)	Solvent content (%)	VOC emissions (kg per B747)
Paint removal	Chemical stripping agent	3 000		No VOCs <sup>(1)</sup>
Pretreatment	Wash primer based on polyvinyl butyrate containing chromate	240	76	182
	Primer containing chromate	450	67	301
	Primer chromate-free	450	71	319
Cleaning	Butyl acetate, butyl alcohol	200	100	200
Topcoat	High-solid	1 200	43	516
	Solvent-based	1 300	61	793
Clear coat	Solvent-based	1 200	65	780

<sup>(1)</sup> No VOCs according to the definition of the IED.

Source: [13, DFIU and IFARE, 2002]

According to the utilised paint system, the VOC emissions amount to 1.2–2.3 t per coated Boeing 747-400. If high-solid topcoats are utilised, the VOC emissions amount to about one tonne less, compared to conventional topcoatings and an additional clear coat layer. Waste gas treatment equipment, e.g. oxidisers, are not installed due to large volume flows (approximately 450 000 m<sup>3</sup>/h) and low VOC concentrations.

Different types of aircraft are completely or partly coated in the plant, the coating of 150 aircraft (A300) per year is considered as a benchmark for calculating the level of VOCs being emitted in one year. For 2000, it was calculated that 67 t VOCs was emitted. The emission value of 150 kg/h is exceeded temporarily for some coating processes due to the simultaneous paint application from several employees (up to 12 painters).

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## 5.4 Techniques to consider in the determination of BAT for the coating of aircraft

In Chapter 17, techniques are discussed which might also be applicable to the coating of aircraft. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to the coating of aircraft. In Table 5.6 the general techniques relevant for the coating of aircraft that are described in Chapter 17 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

**Table 5.6: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### 5.4.1 Conventional solvent-based materials

#### Description

Conventional solvent-based paints contain the following solvent contents by weight:

- wash primer: 70–90 % solvent containing chromate, based on polyvinyl butyrate, or epoxy or polyurethane resin;
- primer: 50–67 % solvent containing 10–12 % chromate, based on epoxy or polyurethane resin;
- primer: 71 % solvent, chromate-free;
- topcoat: 55–65 % solvent;
- clear coat: 65 % solvent.

#### Achieved environmental benefits

No data submitted.

#### Cross-media effects

No data submitted.

#### Operational data

The selection of the lacquer system depends on manufacturer defaults, international regulations and customer requests. It is common practice to treat the waste gases containing solvent.

A reported VOC emission range when applying conventional solvent-based systems for painting the outside of a Boeing 747-400 (without emission controls) is 430–830 g/m<sup>2</sup>, depending on the

utilised paint system. For coating the outside of a new Airbus A321, about 480 g VOC/m<sup>2</sup> are emitted. The surface of the components is about four times greater than that of the outside of an aircraft, e.g. the total surface of the component parts for an Airbus A320 to be coated is about 3 600 m<sup>2</sup>.

For internal coating, including the components of an Airbus A321, an estimated emission factor of 300 g VOC/m<sup>2</sup> is reported.

### **Applicability**

Solvent-based paints can be used in all phases of the painting operation (wash primer, primer, topcoat, clear coat and repair), and can be used on metals and plastics. Since the manufacturer's corrosion protection guarantee lasts for 25 years, and as required by aircraft type approval regulations, only specific paint systems can be utilised.

### **Economics**

No data submitted.

### **Driving force for implementation**

No data submitted.

### **Example plants**

Lufthansa Technik AG, Hamburg, Germany. AIRBUS Deutschland GmbH, Hamburg, Germany.

### **Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004]

#### **5.4.1.1 Manual cleaning with pre-impregnated wipes**

See Section 17.9.4

#### **5.4.2 Replacement of solvent-based materials (substitution)**

##### **5.4.2.1 High-solid paints**

### **Description**

For the general description, see Section 17.7.2.1. Instead of a conventional three-layer system (wash primer, primer and topcoat), a high-solid system consisting of a high-solid epoxy primer and a high-solid topcoat can be utilised. Two-component paints are applied in topcoat and have a solvent content of 30–43 %.

### **Achieved environmental benefits**

Compared to the conventional paint systems, VOC emissions can be reduced by up to 30 %, giving estimated VOC emissions of 200–320 g/m<sup>2</sup> compared to conventional systems, see Section 17.7.2.1.

### **Cross-media effects**

No data submitted.

### **Operational data**

The optical surface qualities and technical properties of high-solid paints are equal to or even better than those of conventional paints.

### **Applicability**

Applicable for the construction and maintenance of new aircraft.

### **Economics**



Material costs and the costs of paint removal for maintenance operations are higher.

#### **Driving force for implementation**

IED.

#### **Example plants**

Widely used.

Lufthansa Technik AG, Hamburg, Germany. Airbus Deutschland GmbH, Hamburg, Germany.

#### **Reference literature**

[13, DFIU and IFARE, 2002] [78, TWG, 2005]

### **5.4.3 Replacement of hexavalent chromating (substitution)**

The application and treatment of hexavalent chromating and its replacement by other options is covered in the STM BREF [59, EIPPCB, 2006].

Wash primers and primers containing chromate are used for increased corrosion protection for climate conditions with a high humidity and high salinity of the atmosphere or upon customer's requests. Primers are applied by using electrostatically assisted spraying.

A chromate-free primer can be applied if the aircraft is utilised under regular climatic conditions. However, the wash primer containing chromate cannot be substituted for safety reasons [13, DFIU and IFARE, 2002].

A chromate-free primer is reported to be available which may replace the separate wash primer and primer for corrosion resistance [78, TWG, 2005].

### **5.4.4 Paint application techniques and equipment**

#### **5.4.4.1 Electrostatically assisted spraying**

For a general description, see Section 17.7.3.14. These techniques are commonly applied.

#### **5.4.4.2 Wet separation spray booths**

For a general description, see Section 17.10.4.1. This technique is increasingly applied in the automated coating of aircraft components.

#### **5.4.4.3 Components painting – enclosure and automated application**

##### **Description**

Component parts are increasingly painted by applying automated painting processes in enclosed spray booths equipped with waste gas treatment (see Section 17.10.2.1).

##### **Achieved environmental benefits**

This reduces the overall VOC emissions for an aircraft as the surface of the components is about four times greater than that of the outside of an aircraft, e.g. the total surface of the component parts for an Airbus A320 to be coated is about 3 600 m<sup>2</sup> compared with the 1 200 m<sup>2</sup> of the fuselage.

##### **Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

Airbus France, Nantes, France.

**Reference literature**

[13, DFIU and IFARE, 2002] [110, Eurocar, 2005]

**5.4.5 Waste gas treatment**

**5.4.5.1 Venturi particle separation**

Venturi systems are used to improve the efficiency of wet dust collectors (see Section 5.4.5.2).

For a general description, see Section 17.10.4.1.

[13, DFIU and IFARE, 2002]

**5.4.5.2 Scrubber**

For a general description, see Section 17.10.4.1. For the deposition of overspray, wet dust collectors are installed. An achieved emission level of  $< 1 \text{ mg/m}^3$  of dust from spraying is reported.

[13, DFIU and IFARE, 2002]

**5.4.5.3 Treatment of waste gases from body painting**

The application onto aircraft is done in closed workshops (see Section 17.10.2.1) and completely by hand with an application gun. Waste gas treatment is not typically applied due to substantial volume flows (about  $450\,000 \text{ m}^3/\text{h}$ ), low VOC concentrations and the discontinuous operation of installations.

[13, DFIU and IFARE, 2002]

## 6 COIL COATING INDUSTRIES

### 6.1 General information on coil coating

[22, ECCA, 2004] [38, TWG, 2004] [78, TWG, 2005]

*TWG please provide updated information for Section 6.1*

The definition of a coil coating process according to EN-10169-1:1996 is as follows: *'A method in which an organic coating is applied on a metal strip in a continuous process. This process includes cleaning and chemical pretreatment of the metal surface and either one-side or two-side, one or multiple application(s) of (liquid) paints or coating powders which are subsequently cured, or laminating with plastic films'*.

The substrate is normally either cold rolled, zinc- or zinc-alloy-coated steel (75 %) or aluminium (25 %) expressed as surface area. Of the coatings, 95 % consist of paints and 5 % of plastic laminates. The latter coating type is experiencing rapid growth at present, particularly as a combination of prepainting and laminating.

The coated coil process gives the option of a wide range of colours, gloss levels and surface textures. The coil can be delivered in coil form, slit or as cut lengths; it can be subsequently bent, profiled, deep-drawn, fastened, etc., without detriment to the surface coating. All stages of the process are under continuous control, e.g. the chemical bath concentration and temperature, coating thicknesses, colour, gloss, adhesion and mechanical qualities of the coating.

#### 6.1.1 Size of the coil coating industry

Most of the coil coaters in Europe are integrated companies in large steel or aluminium groups, normally supplying big quantities of pre-coated metal. Some coil coaters such as coil coaters of narrow strips and specialised service centres (~~increasingly becoming more common~~), for example, deliver smaller and more customised quantities to the user.

Currently there are around 390 lines worldwide (outside North and South America) installed in 50 countries, with new capacities still emerging, showing the growing demand.

Table 6.1 gives the number of production lines by country in Europe and the yearly production volumes of pre-coated steel and aluminium. It is not known if all of these fall within the scope of the IED IPPCD.

Table 6.1: Number of production lines and yearly production of pre-coated steel and aluminium in some European countries

	Number of production lines	Yearly volumes of prepainting coil lines	
		Steel (kt/yr)	Aluminium (kt/yr)
Austria	2	375	
Belgium	7	670	8
Denmark	3	20	10
Finland	2	270	*
France	17	1 415	45
Germany	24	1 469	382
Greece	4	60	50
Ireland	0	0	0
Italy	34	1 225	197
Luxembourg	0	0	0
Netherlands	15	170	55
Portugal	2	40	*
Spain	18	428	68
Sweden	13	350	*
United Kingdom	9	510	10
Czech Republic	1	40	
Hungary	1	90	*
Poland	4	200	10
Slovak Republic	2	80	5
<b>Total</b>	<b>158</b>	<b>7 412</b>	<b>840</b>
			<b>8 252</b>

\* Steel and aluminium data are not split so the total has been considered in the steel figures.  
Source: [22, ECCA, 2004]

Pre-coated sheet metal products are widely used in industries as varied as building and construction, consumer products, the automotive industry, furniture, lighting, technical packaging, etc. The scale of the uptake of pre-coated products can be seen in Table 6.2 where 2002 figures for pre-painted steel and aluminium are listed.

Table 6.2: Coil coating statistics for 2002

	Steel		Aluminium	
	(kt)	(%)	(kt)	(%)
ECCA	4 674	31.3	344	36
NCCA	4 179	28	558	58.4
Rest of World	6 064	40.7	53	5.6
<b>Total</b>	<b>14 917</b>	<b>100</b>	<b>955</b>	<b>100</b>

NB:  
ECCA = European Coil Coating Association.  
NCCA = National Coil Coating Association (of the United States).  
Source: [22, ECCA, 2004]

## 6.2 Applied processes and techniques in coil coating

[175, ECCA 2016] [174, FI 2016]

A coil coating line coats metallic substrates of coiled strip products with paint or a laminate. These are typically applied onto cold rolled, hot-dip or electro-galvanised steel or aluminium; copper alloys, stainless steel and other metal substrates can also be coated.

### 6.2.1 Typical coil coating line process description

#### 6.2.1.1 Stand-alone line

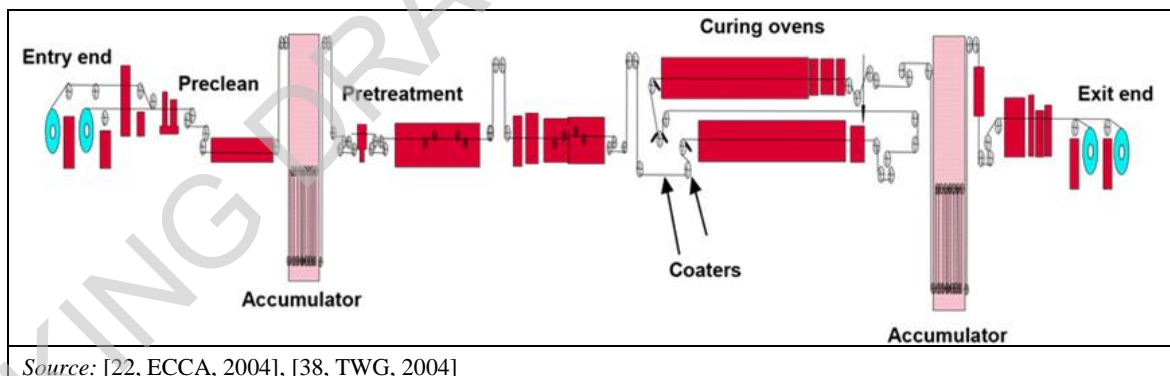
The most common case is an organic coil coating line comprising decoilers, an entry strip accumulator, cleaning, conversion coating, prime coating, finish coating, an exit accumulator and recoilers. This configuration allows the line to operate continuously at high speeds for seven days a week, 24 hours a day, for maximum efficiency. All process parameters are controlled to assure effective operation.

Table 6.3 shows the typical operating parameters of an organic coil coating line, and Figure 6.1 the basic layout of the line.

**Table 6.3:** Typical operating parameters of an organic coil coating line

Parameter	Value
Operating speeds (m/min)	30–180
Gauge (mm)	0.1–3 ±
Width (mm)	150–> 1 600
Coating thickness (µm each side)	± 3–200

Source: [22, ECCA, 2004], [38, TWG, 2004]



**Figure 6.1:** Typical layout of a coil coating line

TWG please provide better figure, if possible

The next sections explain the different parts of the coil coating line in more detail.

#### 6.2.1.1.1 Entry

The coiled strip is fed into the line by a coil car and pay-off reel. The coil is measured checked to ensure compliance with quality standards, and then passed through a shearing process to remove any damaged material from the leading edge. A stitch or weld is created between the leading edge of the new coil and the end of the coil already being processed in the line, to allow a continuous flow of material through the processing section. The strip then goes through a notcher, which allows the stitch to be tracked through the line.

#### 6.2.1.1.2 Leveller

Tension levelling may then be used to ensure that a good standard of flatness is achieved. This is required to facilitate the passage of the material through the roller coaters and ovens, and to meet customer requirements. Poor strip shape can result in an uneven paint layer and scratches. The location of the leveller can in some cases be after the entry accumulator.

#### 6.2.1.1.3 Accumulator

After the leveller, the strip enters an entry accumulator. This normally operates to full capacity but will release stored strip to allow sufficient time for the entry section to stop and stitch or weld coils together.

#### 6.2.1.1.4 Cleaning section

It is common to have a preclean section before the entry accumulator because some lines operate with coils of cold-rolled steel (CRS) which were previously oiled to prevent corrosion. It is very difficult to guide an oiled strip, so precleaning the strip before the accumulator makes it possible to operate at a normal speed. In some cases, lines may have cleaning sections before and after the accumulator. However, the current trend is towards using hot-dip galvanising (HDG) coil, which does not require cleaning before the accumulator and in some cases may not require cleaning at all, in which case the line does not have this section.

The strip is chemically cleaned and degreased in a warm aqueous cleaning solution, via a dip and/or spray system (sprayed both sides). It is essential that the surface of the strip is free from impurities, such as grease, oil or abraded metallic fines, so that it can be fully coated with the conversion coating, thus ensuring the optimal performance of the final product. Cleaning is followed with hot and cold water rinses to remove all residual chemicals. A squeegee roller set-up is generally used to ensure that low carryover from the degreasing section occurs and to minimise the amount of waste water. A 'pre-cleaning' section may be installed before the entry accumulator in case of heavily soiled substrates.

#### 6.2.1.1.5 Conversion coating (pretreatment)

The strip is dried prior to being treated with a conversion coating. A pretreatment is necessary both for ensuring the correct adhesion of the paint layer(s) and good corrosion-resistant behaviour. The choice of the chemicals used in the surface treatment bath is based on their ability to achieve these two objectives, adhesion and anti-corrosion.

The usage of ~~This coating usually contains chromic or chromium~~ Cr(VI)-based free salts has been extensively adopted over the last decades because Cr(VI) is well known ~~and~~ to provides an activated surface that enables the organic paint layer to adhere to the metallic surface of the strip. For metals such as cold and hot rolled steel and various forms of galvanised steel, a coating of iron or zinc phosphate, or titanium-fluoride-based treatment, may be applied instead. Special additives will also typically be used to promote the coating deposition on different metals and to increase process efficiency.

Due to legislation increasingly restricting the use of Cr(VI), the coil coating sector has already largely shifted from Cr(VI)-based products to Cr(VI)-free products. The eradication of Cr(VI) is not always easy among the diverse coil coating business segments, and, with a wide range of metallic substrates, for some products the replacement of Cr(VI) with safer chemicals is

difficult. However, even in these difficult cases, the replacement of Cr(VI) is planned before the 'sunset date' defined by REACH (unless specific authorisations are given).

~~The presence of this conversion coating improves the paint adhesion and humidity resistance, and hence improves the longer term corrosion resistance of the final product.~~ The coating can be applied via a chemical roller coater ('chemcoater', which does not require rinsing<sup>21</sup>) or by a spray or dip followed by squeegee rollers. Some coatings require a final rinse to remove any residues left on the strip ~~component, the component~~ which is ~~oven~~ dried before entering the coating section.

#### 6.2.1.1.6 Primer coat application

The painting process comprises two stages, namely the primer application and the finish application. In the first stage, the strip passes through a roller coater machine that applies a primer to one or both sides of the strip. The roller coater can be adjusted in order to regulate the amount of paint applied onto the strip surfaces. Application ~~Coating~~ operations are carried out in an enclosed area with forced ventilation to ensure safe working conditions for personnel. ~~that is adequately ventilated to ensure safe working conditions for personnel under local and European regulations.~~ A meter roll presses the strip towards a pick-up roll and helps to control the wet film thickness of the paint. Normally primer paint is applied by using the two-roller technique (pick-up roller and application roller).

After application of the primer, the strip passes through an oven, the temperature and residence time of which is controlled to ensure that all the volatiles are removed and that the paint is properly cured. This will be dependent on the paint system applied and the cross-sectional area of the strip. After the oven curing, the strip is cooled by ~~either~~ an air and/or water cooling system, ~~and in some instances both.~~

#### 6.2.1.1.7 Finish coat application

Once dried, the strip passes through a second roller coater machine, which applies the finish paint coat to either one or both surfaces. A similar or different coating may be applied to the reverse side of the coil. Paint can be applied to either or both the top and bottom sides of the strip using two rollers (pick-up and application rollers) or three rollers (meter, pick-up and application rollers) depending on the product. In the finish coater, there are two different painting heads for the top side of strip and also two different painting heads for the bottom side. This makes it possible to do a quick colour change on either side of strip. Again, the thickness of the paint applied to each side of the strip can be controlled. The strip then passes through an oven set at an appropriate temperature to ensure that all the volatiles are removed and that the paint is fully cured. After the oven curing, the strip is cooled by either an air and/or water cooling system, ~~and in some instances both.~~

~~For the production of plastisol products, an embossing roller may be used to imprint a pattern into the hot paint surface prior to quenching.~~

The adhesive required for the production of laminated materials can be applied with either of the roller coater heads. It is subsequently cured in an oven and then processed through the laminator.

All coating operations are normally carried out in an enclosed area that is adequately ventilated to ensure safe working conditions for personnel under local and European regulations.

<sup>21</sup> Also known as 'dry-in-place' or 'no rinse'.

#### 6.2.1.1.8 Embossing and laminating

Embossing rolls are used to imprint patterns or textures into the thicker coatings (such as plastisol products). Embossing is followed by quenching and drying.

For the production of laminated materials, rolls of thin polymer film are bonded to the strip with or without a separately applied adhesive. ~~The film is laid on to the hot coating by roll pressure, followed by quenching and drying as for paint coating.~~ When producing laminated materials, adhesive is applied by a finish coater and activated in an oven before processing through the laminator and water cooling.

#### 6.2.1.1.9 Cooling systems

In order to minimise water usage, consistent with the product quality, an evaporative or other cooling tower may be used to provide a closed system for strip cooling.

#### 6.2.1.1.10 Exit

After being cooled, the strip passes through an exit accumulator and guillotine/shears. This accumulator allows the line to run continuously while the exit section slows or stops in order to remove a finished coil. The strip is inspected and tested to ensure that it complies with quality standards, and is then coiled onto a tension reel. The completed coil is removed and strapping is applied. It is then identified and moved to the packing area, where it is packed according to customer requirements.

#### 6.2.1.2 Combiline

Metal-coated steel is the most common substrate used in the steel coil coating industry. In the plants where both hot-dip galvanizing and painting activities were already present, the idea of merging these two processes on the same industrial line was investigated very early as a potential cost-effective industrial layout. However, for a long time the discrepancy between the constraints of a hot-dip galvanizing line and those of a coil coating line made it either unrealistic or limited to a very narrow product range. Only a few combilines were available worldwide.

Over the last decade, the technical improvements of both the paints used in coil coating and curing technology made it possible to reasonably combine these two steps without unnecessary constraints and combilines have become a common tool.

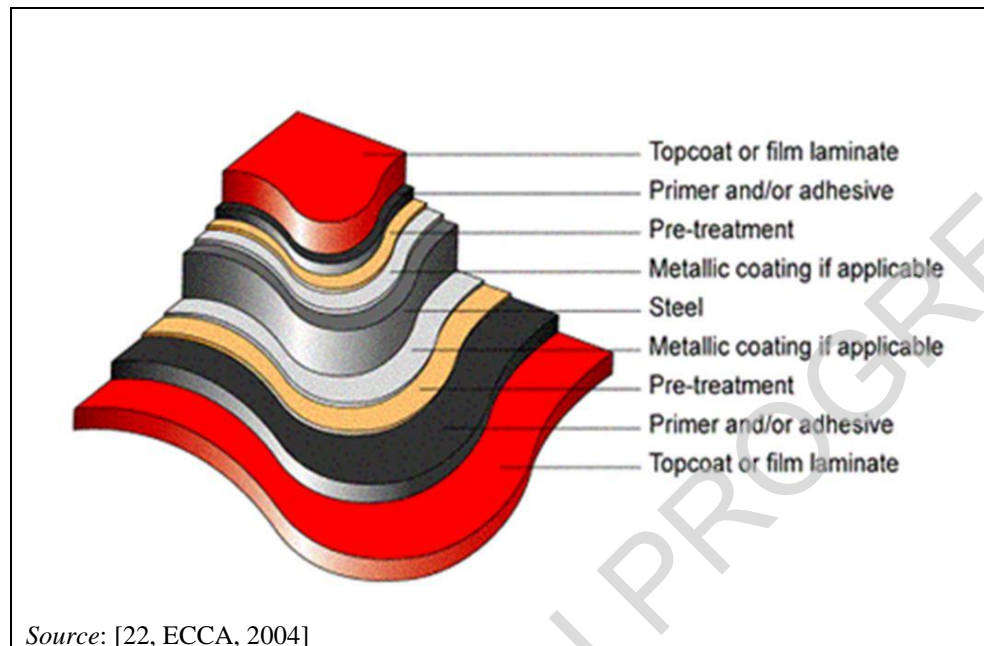
The painting section is generally located right after the temper mill of the hot-dip galvanizing line, in the central section of the line (i.e. in between the two accumulator towers). The line speed is the same for galvanizing and for painting. For the coating activity, the strip passes through the same process steps as a simple coil coating line.

### 6.2.2 Coating types

As the coil coating line has the ability to apply paint or laminate to a substrate, a large variety of products can be manufactured. The coatings, which mainly include polyesters, polyvinylidene fluoride (PVF<sub>2</sub> or PVdF), polyurethanes, plastisols, epoxy and epoxy phenolic coatings, primers, backing coats and laminates, are typically applied in thicknesses of between a few microns ± and 200 microns. It is also possible to find some polyamide or acrylic coatings. The paint usually contains the appropriate additives or particles that will also give the correct overall behaviour (aspect, mechanical properties, ageability).



A flexible anticorrosive primer or a base coat is applied onto the pretreated metallic sheet strip to give good adhesion and durability to the subsequently applied topcoat. For each product, the coating is built up in a number of layers. A typical example for coated steel material can be seen in Figure 6.2.



**Figure 6.2:** Typical layers of a coated steel product

Table 6.4 lists some typical organic coating types used in the coil coating industry.

Table 6.4: Organic coating types used in the coil coating industry

Coating	Dry film thickness (µm)	Resin types	Solvent content (%)	Solvent types	Cure temperature (°C)
<b>Primers</b> Conventional	4–9	Epoxy/urea, epoxy/melamine, polyester/melamine, polyurethane, acrylic	50–70	High-boiling aromatics; alcohols; glycol ethers/esters; high-boiling esters	210–230
<b>Primers</b> High build	12–25	Polyester/melamine, polyurethane	40–50	High-boiling aromatics; alcohols; glycol ethers/esters; high-boiling esters	210–230
<b>Back coats</b>	4–15	Polyester/melamine, epoxy/melamine, epoxy/phenolic, alkyd/melamine	50–70	High-boiling aromatics; alcohols; glycol ethers/esters	180–250
<b>Topcoats</b>					
Polyester	18–25	Saturated polyesters cross-linked with melamine-formaldehyde resins	35–55	High-boiling aromatics; glycol ethers/esters; high-boiling esters/alcohols	210–250 <del>230</del>
<b>SMP</b> (silicone-modified polyester)	As above	As above except for silicone modification in the polyester resin	45–55	High-boiling aromatics; glycol ethers/esters; high-boiling esters	210–250 <del>230</del>
Polyurethane	20–30	Saturated polyesters with urethane cross-linking	30–50	High-boiling aromatics; glycol ether/esters; high-boiling esters	220–250 <del>240</del>
<b>PVDF</b> <b>PVF<sub>2</sub></b>	20–25	Polyvinylidene difluoride + acrylic polymer	40–65	High-boiling aromatics; glycol ethers/esters; high-boiling ketones	240–260
<b>PVC</b> <b>plastisol</b>	100–200	Polyvinyl chloride + plasticisers	<10	High-boiling esters; high-boiling aliphatics	190–210
<b>Water-based products</b> (includes some primers and back coats)	10–25	Acrylic/melamine	5–15	High-boiling esters; glycol ethers/esters	220–230
<b>Non-stick bakeware coatings</b>	12–15 (2-coat 7+7)	Polyether-sulphone PTFE	65–80	<del>N-methyl pyrrolidone;</del> Butyrolactone; high-boiling aromatics	350–370
<b>Laminate film coatings</b>	15–120	Polyvinyl chloride (PVC) Polyvinyl fluoride (PVF) Polyethylene terephthalate (PET) Acrylic Polypropylene	0	None in film, but used in primer/adhesive	Lamination at 180–230
<b>Powder coatings</b>	35–100	Polyester/epoxy polyurethane	0		200–250

Source: [22, ECCA, 2004], [38, TWG, 2004]

### 6.3 Current consumption and emission levels in coil coating

[13, DFIU and IFARE, 2002], [22, ECCA, 2004], [38, TWG, 2004, 78, TWG, 2005]

#### 6.3.1 Mass balances

General consumption and emission data from the coil coating processes are reported in the following sections. However, specific consumption and emission data from some individual plants have also been gathered and reported in the relevant sections below.

Data for 33 coil coating plants were received in the data collection and their analysis is presented in the following sections.

#### 6.3.2 Consumption

[13, DFIU and IFARE, 2002] [22, ECCA, 2004], [38, TWG, 2004] [78, TWG, 2005] [155, TWG 2016]

##### 6.3.2.1 Materials

[78, TWG, 2005] [155, TWG 2016]

Table 6.5 lists the usage of organic coatings in 1993 and 2002.

*TWG please update with fresh information*

**Table 6.5: Usage of organic coatings 1993 and 2002**

Coating types	Relative usage (%)	
	1993	2002
<b>Primers</b>	16.5	20
<b>Backing coats</b>	13.2	16.6
<b>Topcoats</b>		
Polyester	36.1	39
SMP (silicone-modified polyester)	3.4	0.2
Polyurethane	Unknown	6.2
PVdF (polyvinylidene difluoride)	2.7	2.2
PVC plastisol	19.9	14.1
Water-based	0.4	0.2
Laminate films	6	6
Powder	Unknown	~ 0.5
Acrylic (solvent-based) – largely historical	0.3	0.002
Other	7.5	1
<b>Total European usage</b>	<b>95 000 t/yr</b>	<b>158 000 t/yr</b>
<i>Source: [22, ECCA, 2004]</i>		

The following materials are used in organic coil coating processes:

- metallic substrates (i.e. steel, zinc-coated steel, aluminium, etc.);
- paint;
- solvents;
- cleaning and pretreatment chemicals **paint stripper**; *TWG please confirm*
- engineering oils;
- (demineralised) water; *(about 0.3 l/m<sup>2</sup> coil)*
- others: biocides, grease, cleaning materials.

Table 6.6 shows the inputs to the coil coating process, their uses and typical end-of-life destination.

**Table 6.6: Inputs to the coil coating process, their uses and typical end-of-life destination**

Substance	Use	Typical end-of-life destination
<b>Inputs in solid form</b>		
Metal strip (as coil)	Substrate	Product or scrap
Cleaning wipes (fabric)	Cleaning	Licensed removal <del>Can be laundered for re-use</del>
<b>Inputs in liquid form</b>		
Paint	Strip coating	Product / licensed removal / returned to paint supplier for reuse
Solvent	Cleaning and thinning paint	Licensed removal
Cleaning chemicals	Cleaning strip	Treatment plant / licensed removal
Pretreatment chemicals	Pretreatment of strip	Product / treatment plant / licensed removal
Paint stripper	Cleaning paint heads	Licensed removal
Water	Cooling/treatment	Waste stream / effluent
Engineering oils	Lubricant	Licensed removal
Coating oils	Anti-corrosion	Product / licensed removal
Biocides	Water cooling (→ longer use of water) <del>treatment chemicals</del>	Waste stream effluent
<b>Inputs in gaseous form</b>		
Steam or hot water <sup>(1)</sup>	Strip drying/solution heating	Condensate – drain system
Natural gas <sup>(1)</sup>	Fuel	Combustion products to air
Hydrogen	Oven monitoring	Combustion products to air
Ethylene in air	Oven monitoring	Combustion products to air
<sup>(1)</sup> An alternative option is to use electricity.		
Source: [22, ECCA, 2004], [38, TWG, 2004]		

### Organic coating

For the coil coating sector, solvent-based coating systems are widely used ~~almost exclusively~~; (see Table 6.5). Organic coating systems are based on polyester and polyurethane (or a combination of both), epoxy or epoxy-phenolic, and polyvinylidene difluoride (PVdF or PVF<sub>2</sub>). For special surfaces, coatings with thermoplastic foils based on polyvinyl chloride (PVC), or polyethylene terephthalate (PET) are also commonly applied. ~~but~~ They may also include polyvinyl fluoride (PVF) and other polymers.

The resin base for primers may be epoxy, polyester, polyurethane or acrylic, depending on the particular specification. The primer is very important for the corrosion resistance because this layer contains the anticorrosive pigments. Until a few years ago, these anticorrosive pigments were mainly based on Cr(VI) compounds but the sector developed alternative formulations that matured in the late 2000s. Most coil coaters have already replaced Cr(VI)-containing primers with Cr(VI)-free primers. ~~Traditionally, anti-corrosive primers rely on the chemical activity of zinc or strontium chromates to provide corrosion protection. While internal and lower specification systems have performed adequately without chromate pigments, the use of chromate free primers in long life coatings in aggressive environments is not currently established (see the STM BREF [59, EIPPCB, 2006]).~~

The most frequently used solvents have been included in Table 6.7.

**Table 6.7: Solvents most frequently used in organic coating**

Type of solvent	Some examples
Alcohols	Diacetone alcohol
Glycol acetates	Propylene glycol methyl ether acetate, ethyl diglycol acetate
Glycols	Butyl diglycol, butylglycol, propylene glycol monomethyl ether
High-boiling esters	Dibasic esters, mixtures of refined dimethyl esters of adipic, glutaric and succinic acids
Ketones	Isophorone
Petroleum hydrocarbons	Commercial aromatic fractions, xylol
<i>Source: [38, TWG, 2004] [78, TWG, 2005]</i>	

Another source reports that, in the United States, the solvents used most frequently include xylene, toluene, methyl ethyl ketone (MEK), butanol, diacetone alcohol, isophorone, butyl carbinol, mineral spirits, ethanol, nitropropane, tetrahydrofuran, methyl isobutyl ketone, isopropanol and di isoamyl ketone and many mixtures of other special solvents [21, Rentz, et al., 1999].

There is an increasing application of thin film coatings (around 3 µm), especially in the vehicle industry, as well as a decrease in the use of polyvinyl chloride plastisols.

The solvent-based paints currently applied have a solid content in the range of 30–70 wt-%. The applied layer thickness for systems based on acrylate, epoxy, polyurethane or polyester varies from less than 1 µm up to 50 µm; however, it is most commonly around 25 µm.

For plastisols with a solvent content of 5–10 %, a layer thickness of up to 200 µm is typical.

For powder coating systems, a common layer thickness is in the range of 60–100 µm.

Typical consumption figures in relation to the application of a layer thickness of 50–60 µm of powder or liquid coating to a square metre of coated coil is shown in Table 6.8.

**Table 6.8: Typical paint consumption in coil coating**

Paint system	Paint consumption (g/m <sup>2</sup> coil)
Solvent-based (50 wt-%)	32–53
Powder paint	60–80
NB: Due to the various coating systems and layer constructions, these figures represent only an approximation.	
<i>Source: [13, DFIU and IFARE, 2002], [38, TWG, 2004] [78, TWG, 2005]</i>	

In Germany, about 22000 tonnes of solvent based paint was applied in 2000. In large installations, solvents are used at a rate of hundreds of kilograms per hour.

Consumables containing non-solvents listed in Table 6.9 include cleaning and pretreatment chemicals. **TWG: Please correct this information, especially the references to Cr(VI)**

Table 6.9: Chemicals containing non-not mixed with solvents

Process	Product	Application method	Substrate	Main components	Consumption rate (kg/1000 m <sup>2</sup> )
Cleaning	Alkali liquid	Spray	Cold rolled steel, zinc-coated steel	Potassium hydroxide, sodium hydroxide, phosphates, sugar-based complexing agent, surfactants	1.6
Cleaning	Alkali liquid	Spray	Aluminium	Potassium hydroxide, sodium hydroxide, phosphates, sugar-based complexing agent, surfactants	2.5
Cleaning	Acid liquid	Spray	Aluminium	Sulphuric acid, phosphoric acid, hydrofluoric acid, surfactants	1.3
Pretreatment	Alkaline oxide (stage 1)	Spray and immersion	Zinc coated steel	Sodium hydroxide, sugar-based complexing agent, ferric nitrate, cobalt nitrate	4.8
Pretreatment	Alkaline oxide (final rinse)	Spray	Zinc coated steel	Cr <sup>6+</sup> , Cr <sup>3+</sup> , Zn, HF	0.94
Pretreatment	Chrome (no rinse)	Chemcoater	Cold rolled steel, zinc coated steel	Cr <sup>6+</sup> , Cr <sup>3+</sup> , phosphoric acid	0.52
Pretreatment	Zinc phosphate	Spray	Zinc coated steel	Zinc phosphate	6.6
Pretreatment	Chrome (rinsed)	Spray	Zinc coated steel	Cr <sup>6+</sup> , Cr <sup>3+</sup>	11
Pretreatment	Chrome-free (no rinse)	Chemcoater	Zinc coated steel	Titanium, manganese, zirconium, phosphoric acid, organic polymer	0.4
Pretreatment	Chrome (no rinse)	Chemcoater	Aluminium	Cr <sup>6+</sup> , Cr <sup>3+</sup> , phosphoric acid	0.52
Pretreatment	Chrome (rinsed)	Spray	Aluminium	Cr <sup>6+</sup> , Cr <sup>3+</sup> , phosphoric acid, hydrofluoric acid	2.00
Pretreatment	Chrome-free (no rinse)	Chemcoater	Aluminium	Titanium, manganese, zirconium, phosphoric acid, organic polymer	0.40
Pretreatment	Chrome-free (rinsed)	Spray	Aluminium	Titanium, zirconium,	2.00
Pretreatment	Chrome-free (no rinse)	Spray and immersion		Zirconium	

Source: [22, ECCA, 2004], [38, TWG, 2004] [78, TWG, 2005]

*TWG please update with fresh information on Cr(VI) usage*

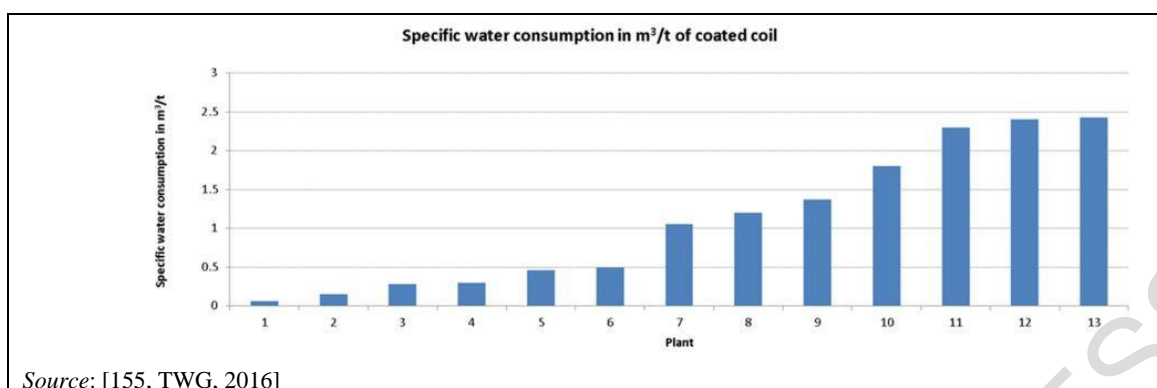
### 6.3.2.2 Water

[155, TWG 2016]

The main water usage is for the cleaning and pretreatment stations, although some is used in quenching after coating and embossing. Techniques and BAT for controlling and reducing water usage are given in the STM BREF. Key techniques identified are ~~are benchmarking consumptions, see Section 0, and the techniques discussed in Section 17.4 (re-use and recycling, regeneration, cascade rinsing, and controls)~~ [78, TWG, 2005]:

- control of water usage at all water-using related processes – mainly in degreasing and rinsing processes and cooling quenches;
- reverse cascade rinsing for the degreasing and rinsing processes;
- treatment of recycled water from degreasing and cooling processes for reuse by using an oil skimmer, sedimentation, magnet separation, particle filter, membrane filtration.

Reported values for specific water consumption in the industry are presented in Figure 6.3.



**Figure 6.3:** Specific water consumption in the coil coating industry (m<sup>3</sup> per t of coated coil) in 2015

### 6.3.2.3 Energy

Natural gas is normally used as the fuel source for the ~~paint-curing~~ ovens when the paint is cured by convection. It is also used ~~and~~ for the oxidiser (combustion process). Commonly, a regenerative or recuperative oxidiser is applied. The heat generated can eventually be used in the process or can be used for steam generation or hot water. Natural gas can also be used to heat the no-rinse coating system oven, which dries the ~~chrome~~ pretreatment solution that has been applied to the strip. Dampers and temperature gauges are used to ensure that the oven settings are controlled. In an integrated steel plant, recovery of energy can be connected to the overall energy system of the site.

*TWG: Site visit (Tata, May 2107) indicated that induction and NIR are also used, sometimes in combination. Please clarify.*

Drying or curing of power coatings is typically carried out by a combination of infrared and circulating hot air, or with NIR or induction ovens.

Electricity is used to power the line and is sourced from the national grid. The main use of electricity is for process operations and coil movements with the overhead cranes and line drives, which are all electrically powered. Typical consumption levels are shown in Table 6.10 and Table 6.11 below.

**Table 6.10:** Electricity use for aluminium and steel substrates

Electricity (kWh/1000 m <sup>2</sup> ) Aluminium			Electricity (kWh/1000 m <sup>2</sup> ) Steel		
Minimum	Average	Maximum	Minimum	Average	Maximum
270	360	375	250	350	440

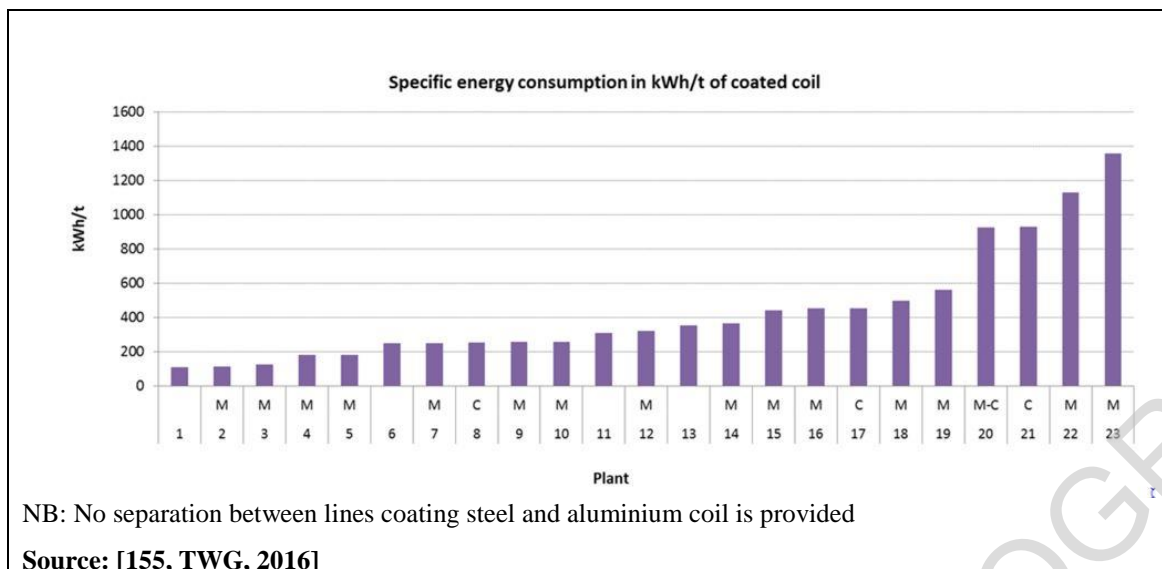
Source: [22, ECCA, 2004]

**Table 6.11:** Fossil fuel consumption for aluminium and steel substrates

Fossil fuels (MJ/1000 m <sup>2</sup> ) Aluminium			Fossil fuels (MJ/1000 m <sup>2</sup> ) Steel		
Minimum	Average	Maximum	Minimum	Average	Maximum
4 000	7 000	9 800	3 000	6 500	10 200

Source: [22, ECCA, 2004]

Reported values for specific energy consumption are presented in Figure 6.4. The reported values are measured (M), calculated (C) or derived by a combination of measurement and calculation (M-C).



**Figure 6.4: Reported values for specific energy consumption expressed in kWh per t of coated coil product**

The main techniques for the minimisation of energy consumption are the following:

- thermal insulation of tanks and vats with heated liquids;
- air seals in dryer ovens;
- reduced air ventilation at idle operation or maintenance;
- exhaust air heat exchanger in ventilation systems;
- air extraction and energy recovery from the drying processes;
- air extraction and energy recovery for the cooling zone;
- heat recovery from waste gas abatement;
- central waste gas treatment with variable frequency drives.

### 6.3.3 Emissions

[13, DFIU and IFARE, 2002] [22, ECCA, 2004], [38, TWG, 2004] [21, Rentz, et al., 1999] [155, TWG, 2016].

Solvents are released as VOC emissions, especially during the process steps of coating (about 8 %), drying (about 90 %) and cooling with water and/or air (about 2 %).

In general, there are four main sources of emissions to air in a typical coil coating line. These are:

- fumes (mist) from the conversion coating section if a dry-in-place or dipping application is not used; *TWG please update with reference to Cr(VI) use*
- paint/solvent fumes from the coaters and ovens;
- fumes volatiles from the paint kitchen and mixing bays;
- emissions from the cooling system; these can be point source emissions or fugitive emissions.

Typical emissions to air are given in Table 6.12 below. All are point sources.



Table 6.12: Typical emissions to air from coil coating processes

Emission source	Species emitted
Oxidiser	VOCs, CO, NO <sub>x</sub>
Finish oven air quench	VOCs
Laboratory fume cabinet	Low-level assorted fumes
Occupational health vent from coating rooms	VOCs
Pretreatment scrubber exhaust	Mist with mineral content <del>Chromic acid</del> Potassium hydroxide Sodium hydroxide
Preclean scrubber	Potassium hydroxide Sodium hydroxide
HCl bulk tank scrubber	HCl fume
Flocculation tank fume	SO <sub>2</sub>

Source: [22, ECCA, 2004], [38, TWG, 2004] [78, TWG, 2005]

Typical emissions to air from point sources with abatement equipment are VOCs, and oxides of carbon and nitrogen.

The VOC and CO emissions for lines with abatement can vary depending on the product being produced. Those with high solvent loads can give rise to higher emission values than those with low solvent loadings. Thicker coatings (e.g. plastisols and laminates) can lead to lower emissions than thin coating layers.

The VOC levels from unabated release points can vary intermittently and at times may be  $> 50 \text{ mg/m}^3$  due to intermittent localised activities within the coater house such as line cleaning ~~downs~~ and tray cleaning. However, their volume in comparison with abated emissions is still very low, although the emissions will need to be reviewed on a site-by-site basis.

**TWG please confirm**

Industry-wide clean gas concentrations of  $< 1-50 \text{ mg C/m}^3$  are achieved. Other possible emissions may include isocyanates from polyurethane products and fluorides from coatings containing fluoride where emission levels are typically  $< 0.1 \text{ mg/m}^3$ . However, fluorides are not emitted from the organic paint systems, and blocked isocyanates are used in some coatings as this eliminates isocyanate emissions. ~~Any emissions  $> 50 \text{ mg/m}^3$  VOC are likely to breach the IED limits and therefore abatement would be required.~~

Table 6.13 shows some specific VOC emission values for different coating systems with an average coating thickness of  $55 \mu\text{m}$ . The VOC content of the plant ovens is in the range  $8.75-9.3 \text{ g/m}^3$ , which is about 22 % of the  $40 \text{ g/m}^3$  LEL.

A capture efficiency of 97 % of all VOC emissions that occur throughout the coil coating process can be achieved; resulting in 3 % fugitive VOC emissions. In the case of a coating system with 50 wt-% solvent content in combination with a removal efficiency of 99 % in the incinerator, about 0.04 kg solvents per kg of used coating solids are emitted.

Table 6.13: Specific VOC emissions for several coating systems

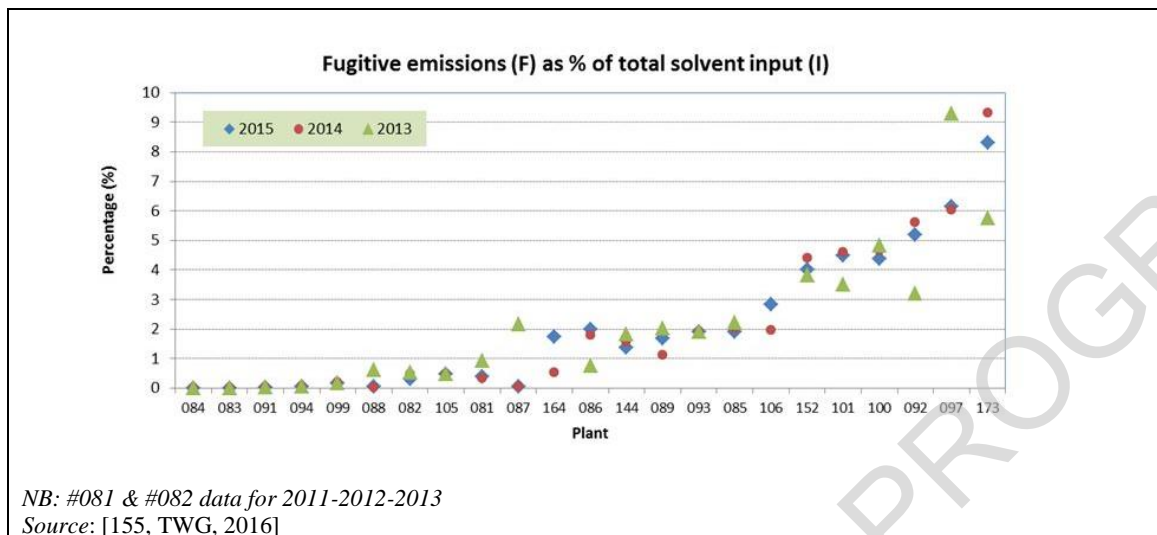
Coating system	Specific VOC emission ( $\text{g/m}^2$ coated coil)	Abatement technique
<b>Solvent-based</b>	0.73–0.84	Incinerator connected to oven
<b>Solvent-based (50 wt-%)</b>	28–29 <sup>(1)</sup>	None
<b>Powder coating</b>	0–0.8 <sup>(2)</sup>	None

<sup>(1)</sup> Concentration values achieved with no further abatement of the air stream.  
<sup>(2)</sup> VOC emissions relate to curing reactions rather than solvents.  
Source: [13, DFIU and IFARE, 2002], [38, TWG, 2004] [78, TWG, 2005]

### 6.3.3.1 Fugitive VOC emissions

[155, TWG, 2016]

The reported values of fugitive emissions (F) as a percentage of the total solvent input (I) for the reference period 2013–2015 are presented in Figure 6.5.



**Figure 6.5: Reported values for fugitive emissions (F) expressed as a percentage of the total solvent input (I) for the reference period 2013–2015**

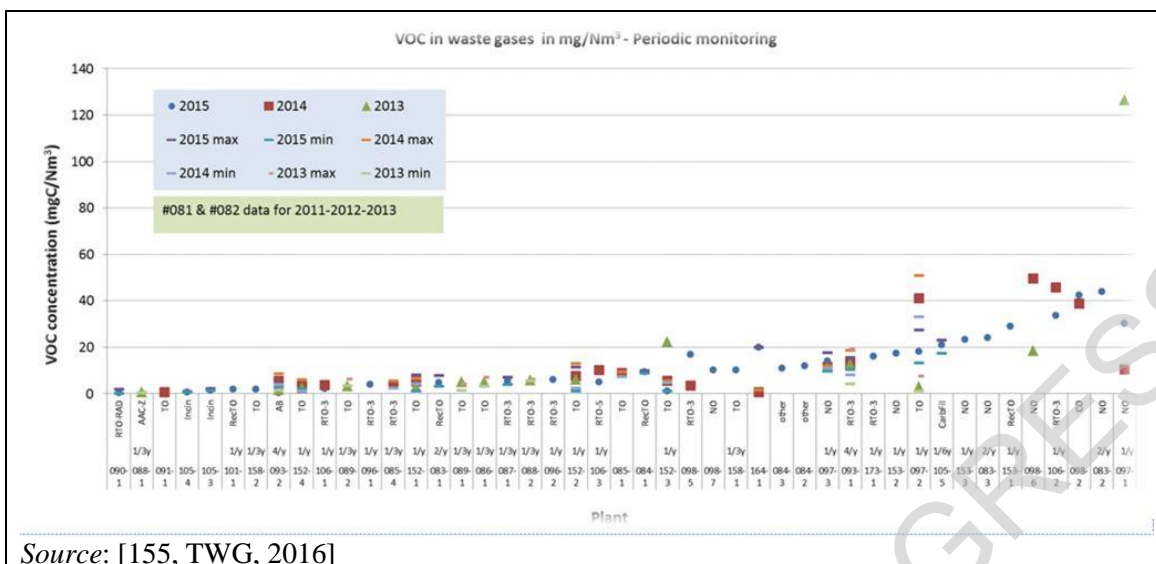
The main reported techniques for the limitation of fugitive emissions are related to:

- general measures to prevent unplanned releases;
- safe storage and handling of hazardous material;
- enclosed application zones with air extraction and subsequent treatment;
- air extraction and subsequent treatment from the drying processes;
- air extraction and treatment from the cooling zone;
- substitution of coatings with a high solvent content by coating with a lower solvent content or a high solid content;
- enclosing of the paint preparation room (kitchen).

The great potential for improvements in fugitive emissions is underlined by the reported reduction of the order of 50 % of fugitive emissions (as a percentage of the total input) at one reference installation achieved by implementing improvements in the paint rooms, especially by improving the extraction processes in the oven and the oxidiser area.

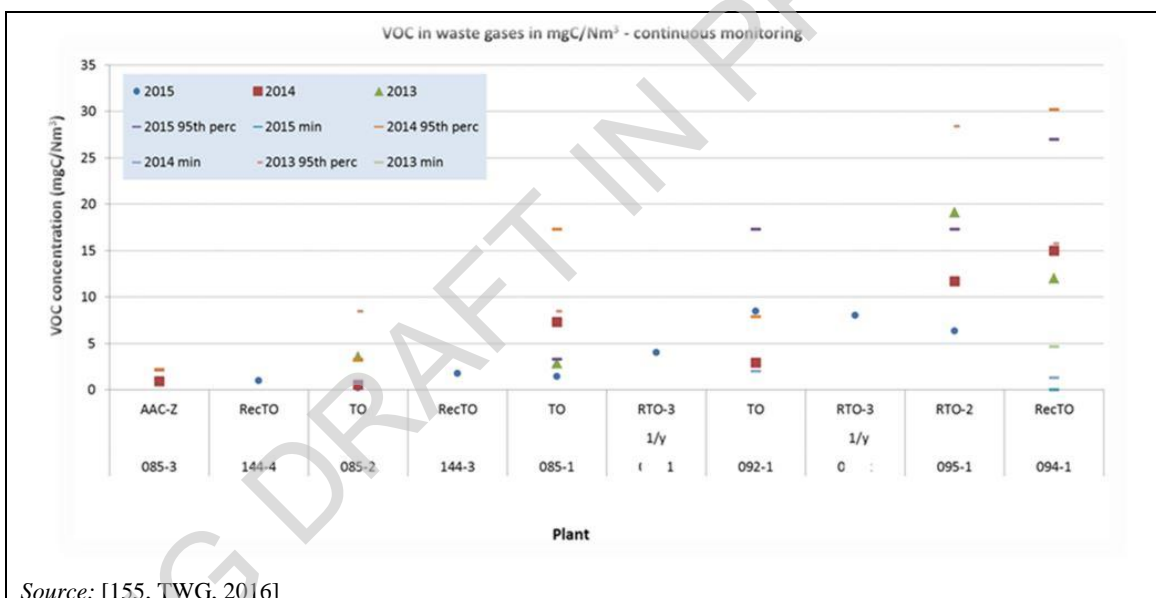
### 6.3.3.2 VOC emissions to air in waste gases

Most of reported VOC emission data are based on periodic monitoring with periodicities that vary from four times a year up to once every three years (see Figure 6.6). Continuous monitoring is performed in fewer cases (see Figure 6.7) while in some cases both continuous and periodic monitoring are carried out.



Source: [155, TWG, 2016]

Figure 6.6: Reported values for periodic VOC monitoring in waste gases, for coil coating plants (mg C/Nm<sup>3</sup>) for the reference period 2013–2015



Source: [155, TWG, 2016]

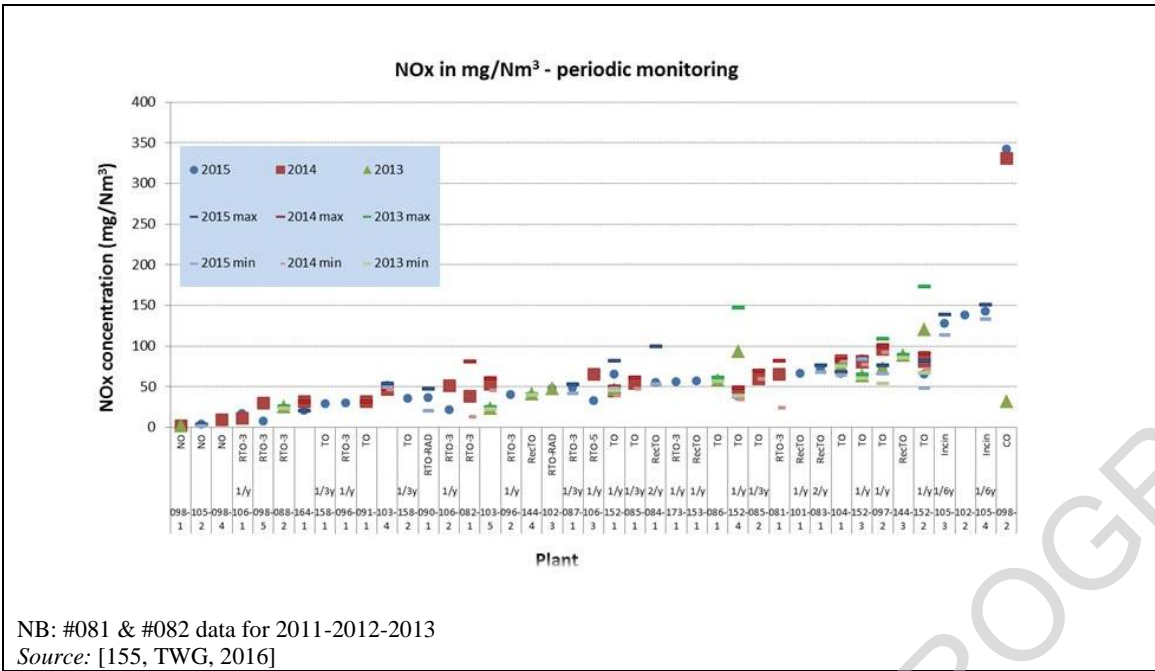
Figure 6.7: Reported annual average values for continuous VOC monitoring in waste gases for coil coating plants (mg C/Nm<sup>3</sup>) for the reference period 2013–2015

### 6.3.3.3 NO<sub>x</sub> and CO emissions to air in waste gases

NO<sub>x</sub> emissions result from the thermal abatement of VOC emissions and are related to the technique applied and relevant conditions. In general, NO<sub>x</sub> emissions are measured on a periodic basis, with the periodicities reported to vary from twice a year up to once every six years.

No techniques were reported as being installed to reduce NO<sub>x</sub> emissions, as the main target of the abatement process is the limitation of VOC emissions. With only one exception, all reported values are below 150 mg/Nm<sup>3</sup>, as an average over the sampling period.

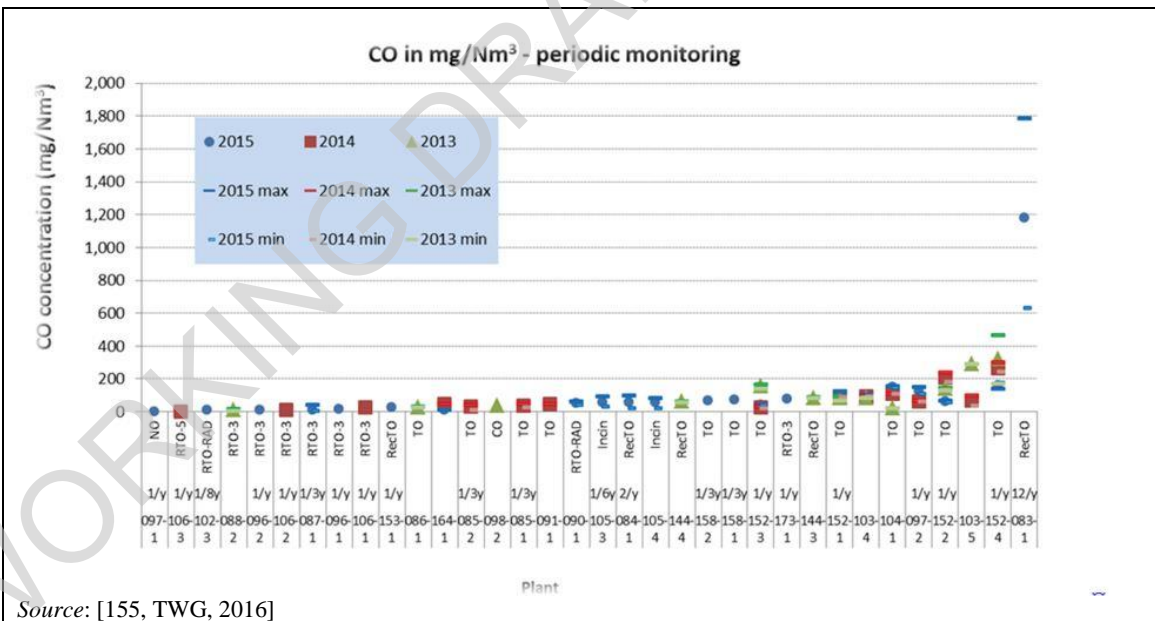
Figure 6.8 shows the reported values for periodic monitoring of NO<sub>x</sub> emissions in waste gases.



**Figure 6.8: Reported values of NO<sub>x</sub> concentration (mg/Nm<sup>3</sup>) for the reference period 2013–2015**

CO emissions also occur from the thermal abatement of VOC emissions and are related to the technique applied and relevant conditions. In general, CO emissions are measured on a periodic basis, with frequencies varying from monthly to once every three years.

Figure 6.9 shows the reported values for periodic monitoring of CO emissions in waste gases from coil coating plants.



**Figure 6.9: Reported values of CO concentration (mg/Nm<sup>3</sup>) for the reference period 2013–2015**

#### 6.3.3.4 Emissions to water

[13, DFIU and IFARE, 2002] [22, ECCA, 2004], [38, TWG, 2004] [59, EIPPCB, 2006]

The main sources of waste water from a coil coating line are from the entry cleaning section and some pretreatment processes that require subsequent rinsing (e.g. ~~passivation, chromatisation~~), and these are discussed in the STM BREF. Pretreatment processes (~~whether they contain chrome or not~~, may also be applied using the 'no rinse method' (application by a roller technique). This method does not generate significant amounts of waste water. Pretreatment and cleaning solutions and their associated rinse waters can either be treated at an on-site effluent treatment plant or taken off site for treatment or disposal.

There are some emissions to the quench water used after curing in the primer and topcoat application, and after embossing but these are not particularly significant. As all paint systems require quenching, there are no differences in the quantities of waste water generated for the different paint systems, but there may be slight differences in the actual levels/types of contaminants. The type of emissions from the cleaning and pretreatment sections for a steel coating line depends upon the metallic substrate and the chemical nature of the cleaning and pretreatment sections. ~~Emissions may include zinc, aluminium, chromium, cobalt, iron, suspended solids, and acid or alkali causing pH variations. A source reported that copper and nickel may be also present. The organic coating used in the steel coating line may also have an influence on the components appearing in the waste waters.~~

Data on emissions to water were reported by 11 installations. The parameters identified<sup>22</sup> as 'main parameters of interest' were: Cr<sub>total</sub>, Cr(VI), nickel and zinc, and fluoride. Other parameters of potential interest were DEHP and NP/NPE.

The main techniques applied are:

- coagulation and flocculation;
- neutralisation;
- sedimentation (settlement);
- filtration (using sand filters).

The exact process sources of the waste waters are not entirely clear in all cases (although this was checked with the type of pre-treatment given). In some cases, no information was given on whether WWT as carried out or the techniques applied. Although the values are small when broken down into categories, there appears to be no differences between emissions from dedicated WWT and combined WWT, or between installations discharging directly to surface waters and those discharging indirectly via urban waste water treatment plants.

Products for the European markets are largely Cr-free. Four installations reported using Cr in pretreatments (but not whether Cr(III) or Cr(VI)). Of these, only one reported carrying out Cr(VI) reduction. Some export products specify Cr pretreatment but it is not clear if REACH registrations will allow this to continue. Only one installation using Cr pretreatment indicated that it also carried out effluent treatment for Cr. This installation only uses Cr(VI) for one product. Other installations report using Cr(III) and/or use a 'Cr dry - no effluent' pretreatment process and intend to move to Cr-free during 2017. **TWG please update with fresh information.**

No WWT for fluoride or phosphate removal were identified and emission values were generally low. No results were reported for DEHP and NP/NPE.

<sup>22</sup> COM working document EIPPCB 09/06/2016: Assessment of Technical Working Group (TWG) data submitted on metals and other emissions to water for their consideration as Key Environmental Issues for installations carrying out IED Annex 1 6.7 activities.

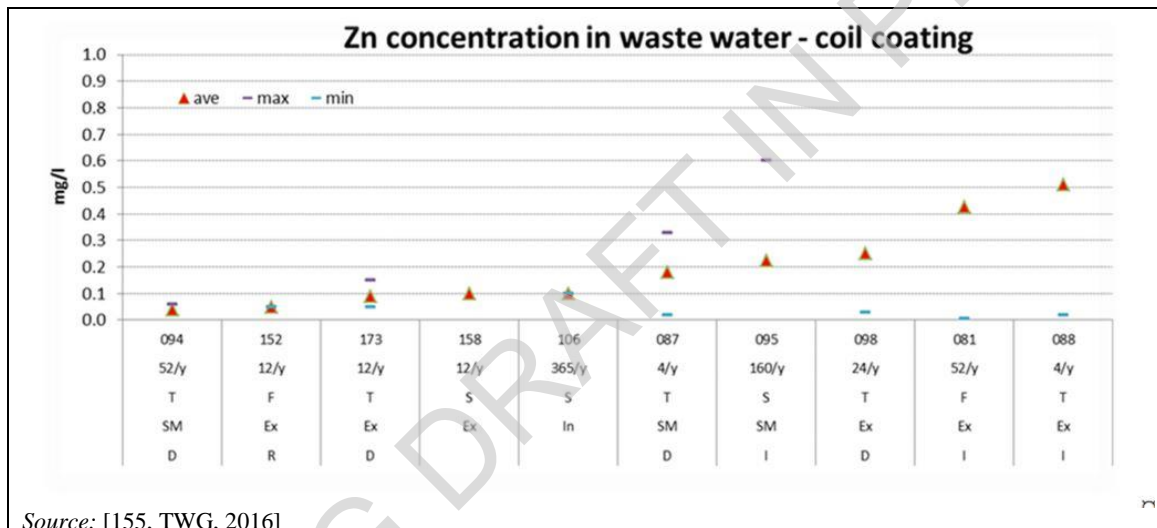
The reported concentration values for each pollutant are presented in the following figures. The abbreviations presented in Table 6.14 have been used along the horizontal axes.

**Table 6.14: Table of abbreviations used in plots for the pollutant concentrations in waste water**

Row	Information	Abbreviation used and explanation		
1 <sup>st</sup>	Plant code number and discharge point code number			
2 <sup>nd</sup>	Sample frequency	x/yr where x is the number of samples taken per year (e.g. 12/yr means monthly, 52/yr means weekly)		
3 <sup>rd</sup>	Sample type	T = Time-proportional	F = Flow-proportional	S = Spot
4 <sup>th</sup>	Monitoring type	E = External	I = Internal	SM = self-monitoring
5 <sup>th</sup>	Discharge type	I = Indirect to sewer	D = Direct to receiving water body	R = Reuse on site

**Zinc (Zn)**

Data for 10 plants were submitted for zinc emissions. The majority of reported values (8 out of 10) are lower than 0.25 mg/l.

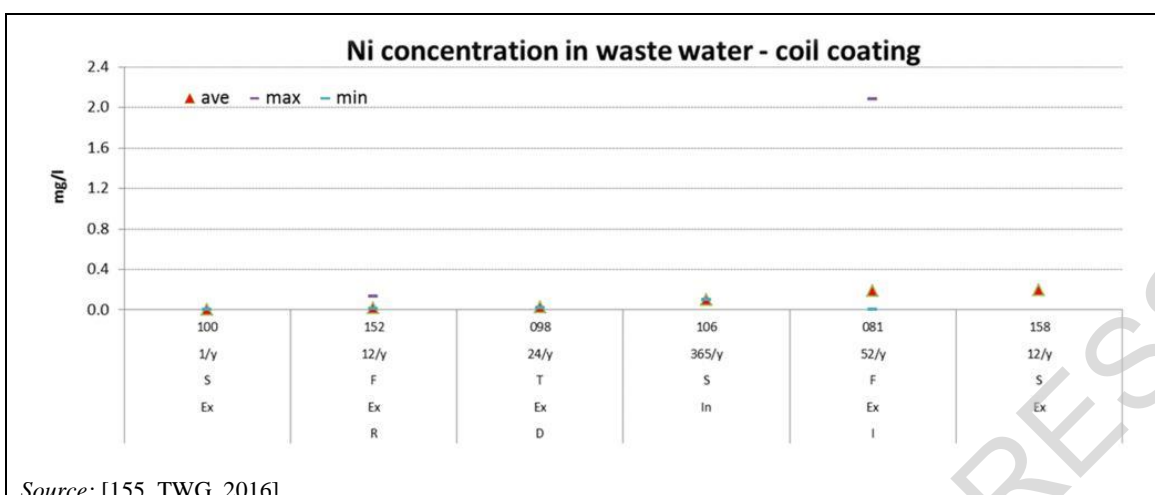


Source: [155, TWG, 2016]

**Figure 6.10: Reported values for Zn concentrations in waste water from coil coating plants in 2015**

**Nickel (Ni)**

Data for only six plants for nickel emissions to water were submitted. All values are lower than 0.2 mg/l.

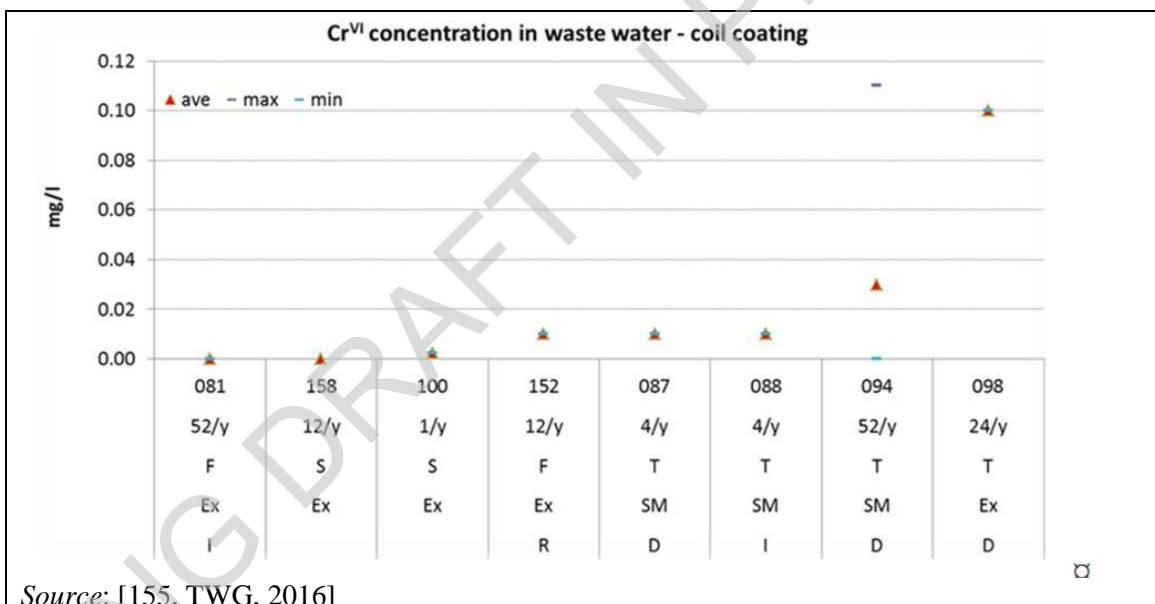


Source: [155, TWG, 2016]

Figure 6.11: Reported values for Ni concentrations in waste water from coil coating plants in 2015

### Hexavalent chromium (Cr(VI))

Data for eight plants for emissions of hexavalent chromium to waste water were submitted. All values are lower than 0.1 mg/l and seven out of eight reported values are lower than 0.03 mg/l.



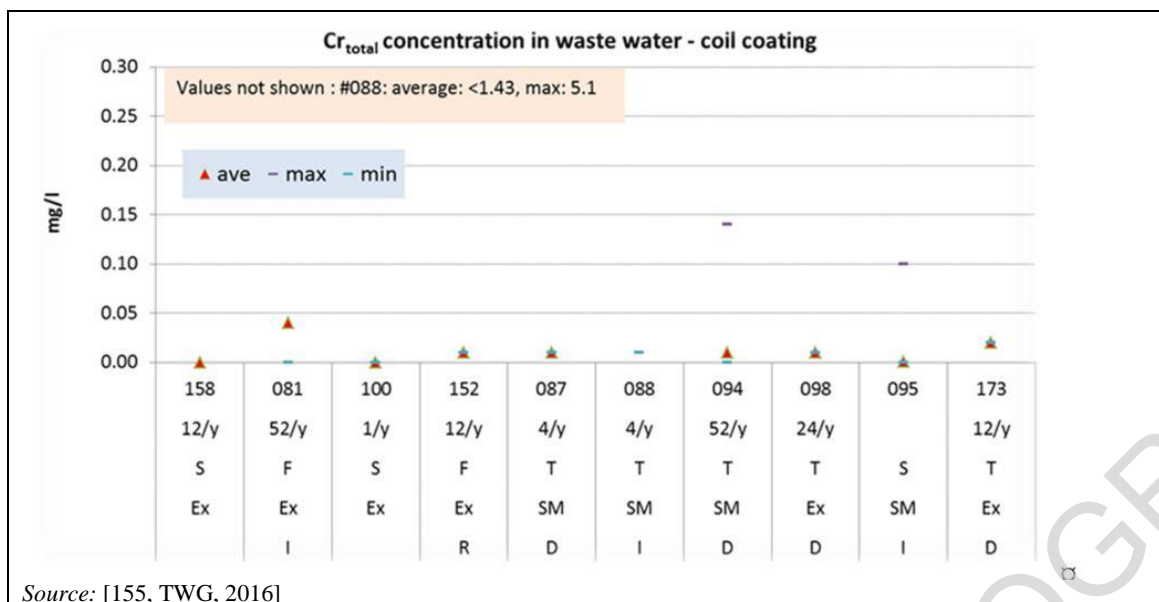
Source: [155, TWG, 2016]

Figure 6.12: Reported values for Cr(VI) concentrations in waste water from coil coating plants in 2015

### Total chromium (Cr<sub>total</sub>)

Data for 10 plants for emissions of total chromium to waste water were submitted, all but one with average values are lower than 0.1 mg/l. The reported values are presented in Figure 6.13 with the exception of the following data:

- Plant 088: average: 1.43 mg/l, maximum: 5.1 mg/l, minimum: 0.01 mg/l;
- Plant 081: maximum: 1.96 mg/l.



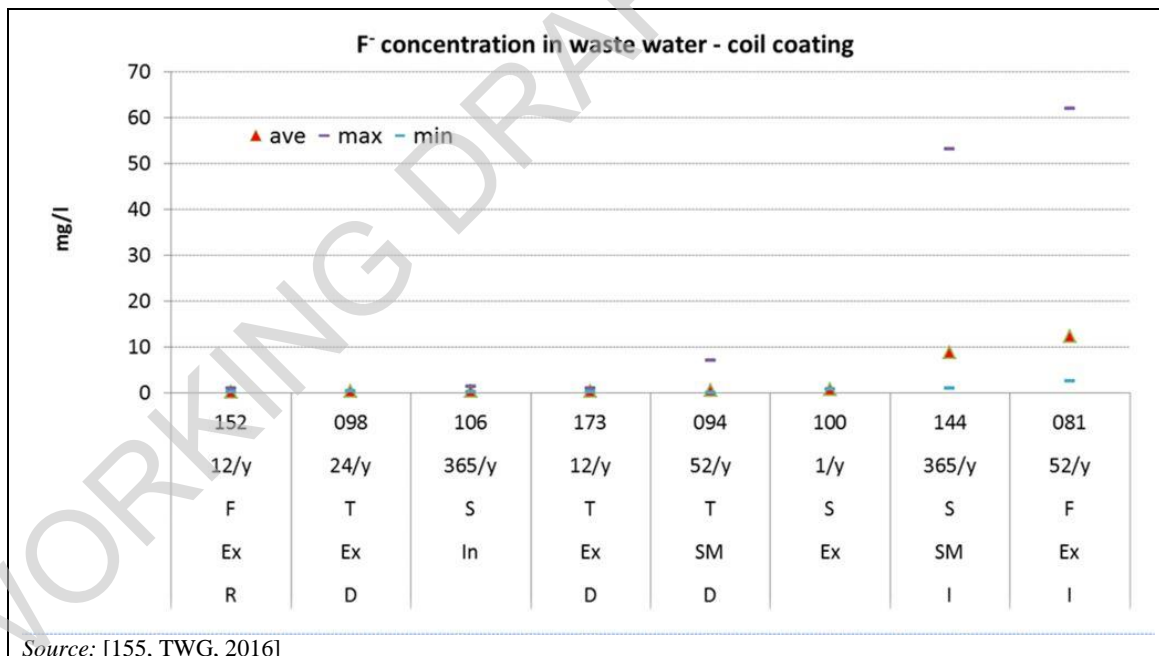
Source: [155, TWG, 2016]

Figure 6.13: Reported values for Crtotal concentrations in waste water from coil coating plants in 2015

**Fluoride (F<sup>-</sup>)**

Data for eight plants for emissions of fluoride to waste water were submitted. The reported values are presented in Figure 6.14. All but two of the reported values are lower than 0.75 mg/l and only two values are of the order of 8–12 mg/l.

Data for Plant 081 refer to the average of the three-year period (2011–2013). Maximum and minimum values are reported considering all the years.



Source: [155, TWG, 2016]

Figure 6.14: Reported values for fluoride (F-) concentrations in waste water from coil coating plants in 2015

**6.3.3.5 Waste generation**

[13, DFIU and IFARE, 2002], [38, TWG, 2004] [155, TWG, 2016]



The main types of waste generated from the coil coating process and their recycling or disposal route are presented in Table 6.15.

**Table 6.15: Main types of waste generated in the coil coating industry**

Process plant source	Source/origin	Quantity (kg of waste per t or product)	Average solvent content (%)	Recycling or disposal route
Waste solvent	Cleaning processes	0.6–2.9	50–100	Delivered off site as hazardous waste
Waste paint and varnish containing organic solvents or other hazardous substances	Production processes	0.02–1.3	40–60	Delivered off site as hazardous waste
Oil emulsion waste	Waste water (pre)treatment	0.04–0.06	NI	Delivered off site as hazardous waste
Paint shop waste (filter materials, solvent-containing wipes and cleaning cloths)	Production / cleaning processes	0.3–2.4	35–50	Delivered off site as hazardous waste
Metal scrap (containers, drums, etc.) and plastic containers	Production processes	0.05–2.1	0.1–3	Returned to supplier
Solvent waste containing halogenated substances	Production processes	1.0–1.3	NI	Delivered off site as hazardous waste
Sludges from waste water treatment facility	Waste water (pre)treatment	0.3–0.8	5	Delivered off site as hazardous waste
PE/PVC waste films	Production processes	0.6–0.8	NI	Delivered off site as non-hazardous waste

NB: NI = No information.  
Source: [155, TWG, 2016]

The cleaning agents containing solvents are used for the cleaning of the coating devices. They are normally collected and treated for re-use. The amount of used solvents in a plant is about 7000 kg/yr. Paint residues are generated in small amounts and are disposed of or re-used for coating the coil's reverse side.

The amount of crystalline iron sulphate from the galvanising process in a plant is about 4000 kg/yr and is externally re-used in smelting processes. The amount of zinc hydroxide is about 7000 kg/yr and this is also re-used in smelting processes.

General (non-hazardous waste) is normally collected in waste containers of varying sizes and design located throughout the plant, and, depending on the contents of the container, is taken to a variety of locations for disposal. General waste includes, for instance, waste packaging material and general rubbish.

Hazardous waste materials are usually tankered off site for disposal or recovery. These can include solvents, paints, contaminated wipes, oils and any other hazardous materials. A suitable recycle/disposal route is normally identified for the material and the necessary checks are made to ensure that the material is passed to a licensed facility. A registered waste carrier is used to transport the material. The necessary transfer note or special waste consignment note is completed and accompanies the waste.

indicates some characteristics of the main wastes arising from a coil coating process and the recycling or disposal route.

Process plant source	Waste or by-product	Recycling or disposal route	Physical state
Scrap metal	Scrap metal	Recycled	Solid
Coating	Waste paint	Licensed removal	Liquid
	Used solvent	Licensed removal	Liquid
	Waste pretreatment	Treatment plant/licensed removal	Liquid
	Alkali cleaners, acid cleaners	Treatment plant/licensed removal	Liquid
	Rinse waters	Treatment plant/licensed removal	Liquid
	Quench waters	Surface water/sewer	Liquid
General	Oil contaminated materials	Licensed removal	Solid
	General waste (including packaging)	General waste to landfill	Solid
	Waste paper (office)	Recycled by licensed contractor	Solid
	Waste engineering oil	Licensed removal	Liquid

Table: Typical wastes from a coil coating line process  
[22, ECCA, 2004]

### Scrap metal

Generally process scrap metal can be recycled or re-used. The amount of scrap metal produced during the process will largely depend on the width and gauge of the substrate being used, and hence is not normally directly correlated to the paint system being manufactured. Aluminium is recovered by remelting in special ovens, where recovery is achieved using energy equivalent to just 5 % of the energy used in its original manufacture. Steel scrap is generally recovered by charging scrap metal, including painted products, into the basic oxygen steelmaking vessel as a raw material. Studies have shown that plastisol-coated steel can also be recycled in this way, with no adverse effect on the emissions from the process. The coating generates energy in return when the steel/aluminium strip is remelted.

### Applied techniques for the minimisation of waste generation

The main reported techniques used for the minimisation of produced waste quantities are:

- use of reusable containers in order to reduce the quantity of scrap metal;
- reusable cleaning wipes;
- reuse of returned paint from the coater head in the course of product change;
- distillation of used solvents;
- vacuum evaporator for the waste water from degreasing, rinsing and demutting; this results in an increase of recycled water and a reduction in the physico-chemical sludge to be disposed of;
- filter press, centrifuges and decanters for waste water sludge to reduce the physico-chemical sludge to be disposed of;
- rinsing system in the pretreatment with no waste water generation;
- improvements to waste handling processes especially focusing on the elimination of sludge waste by increased frequency of collection and elimination of bulk tanker collection;
- reuse of water used to cool the strip after pretreatment.

## 6.4 Techniques to consider in the determination of BAT for coil coating

In Chapter 17, techniques are discussed which might also be applicable to coil coating. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to coil coating. In Table 6.16, the general techniques relevant for coil coating that are described in Chapter 17 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

The EGTEI synopsis sheet for coil coating (see Annex 21.3.1) gives some data on the costs and benefits of some techniques to reduce VOC emissions at a European level. However, the EGTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as cross-media effects, or of the technical characteristics of individual installations.

**Table 6.16: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### 6.4.1 Water management

*These techniques are referred to in Section 17.4 and described fully in the STM BREF*

#### ~~Re-use of water within the plant~~

#### ~~Monitoring rinsing water before discharge by conductivity measurements~~

#### ~~Reverse cascade rinsing~~

#### ~~[Conventional solvent-based coatings]~~

~~**Description:** The majority of coil coating paints are solvent based, with solvent contents from less than 10 % up to more than 70 % for some specific purposes. The emitted VOCs are captured and abated. For more details, see Section 0;~~

~~**Achieved environmental benefits:** Reduced VOC emissions.~~

~~**Cross-media effects:** No data submitted.~~

**Operational data:** No data submitted.

**Applicability:** No data submitted.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002], [38, TWG, 2004]

## 6.4.2 Material-based techniques [~~Replacement of solvent-based coatings (substitution)~~]

### 6.4.2.1 Conversion coatings

*ESVOC considerate as important*

*These techniques are referred to in Section 17.4 and described fully in the STS BREF*

A conversion coating is a protective surface layer on a metal that is created by chemical reaction between the metal and a chemical solution. It can also provide improved adhesion for subsequent coatings, such as paint.

Conversion coatings including hexavalent chromium conversion with substitution and control techniques are discussed in the STM BREF [59, EIPPCB, 2006]

Conversion coatings in coil coating have traditionally used Cr(VI) (chromate) rinses widely, after the pretreatment. However, under the REACH Regulation<sup>23</sup>, the Cr(VI) compounds used in such rinses have a 'sunset date' of 21 September 2017, when they will require specific authorisation for each use.

### ~~Conversion coating containing chrome~~

*NOT considered as a BAT candidate*

### 6.4.2.2 Chrome-free conversion coatings

*Although this technique is partly described in the STM BREF, the change of the CMR status of Cr(VI) has changed since the STM BREF was drafted, and the REACH regulation introduced. It is proposed to provide brief up-to-date information mentioning on current options for coil coating here, while leaving a full discussion to the revision of the STM BREF.*

*The TWG are therefore asked to supply information on the materials or techniques used to replace Cr(VI) compounds.*

### 6.4.2.3 High-solid coatings

#### Description

Usually, solvent-based paints used in coil-coating have a solid content of  $\approx 40\%$ .

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<sup>23</sup> Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

High-solid coating systems with a solid content of 70–95 % can also be applied in coil coating processes for some specific applications.

### Technical description

See Section 17.7.2.1.

PVC plastisol coating is a common product in coil coating and it generally contains less than 10 % solvent. These made up around 12.5 % of coil coating topcoats in 2016, but they are applied at a much higher film thickness. PVC plastisol is by far the most widely used 'high-solid coating' in coil coating.

### Achieved environmental benefits

~~Reductions in extracted VOCs place a lower demand on the abatement equipment. Reduced solvent loadings within the ovens may allow reductions in extracted airflows or increased line speeds for a certain concentration in the air. This reduces the use of gas in the oxidiser, reduces the use of solvents and lowers the volumes to transport.~~

### Environmental performance and operational data

**Cross-media effects:** ~~The reduction of solvent vapours in the waste stream may increase the demand for gas/fossil fuel in the oxidiser, and/or reduce the energy recovered for preheating the oven air.~~

There is a trend to reduce solvent contents in other coating chemistries consistent with the application properties and performance demands of the finished product. It is however difficult to find a balance between coatability (i.e. low viscosity), realistic process conditions (i.e. roller coater parameters, especially roll pressure) and thickness (i.e. 20 µm dry thickness for standard coil-coated product).

### Cross-media effects

When the target thickness is higher than with standard coating, the low solvent concentration is balanced by the higher thickness and the overall solvent content in the air extracted from the oven is more or less the same. If the target thickness is closer to that of standard coating, the reduction of solvent vapours in the waste stream may increase the demand for gas/fossil fuel in the oxidiser, and/or reduce the energy recovered for preheating the oven air.

### Technical considerations relevant to applicability

Generally applicable where performance and economic criteria are met, which in the case of coil coating means some high-thickness products. Extra/different equipment is required for application of PVC plastisols.

~~These are not suitable for all applications. Utilisation of high solid technology is limited by its ability to meet the application properties and performance demands. High solids alternatives are not yet available to meet the performance specifications for many coil coating end-uses.~~

### Economics

Higher solids content coatings require application at a reduced wet film thickness to achieve the same final dry coating thickness. In the rare cases that this is possible, this places greater stresses on the application rolls and may incur higher maintenance costs and increased electrical energy to drive the coater.

### Driving force for implementation

- ~~Reduced solvent loads within the ovens may allow higher line speeds — increased efficiency, reduced energy demand.~~
- For plastisol, the driving force is the market demand for this specific product.
- For other products, the main driver is the potential cost reduction with a lower price per applied micron as coil coaters buy paints per kilogram.
- There is generally pressure of both coil-coaters and paint suppliers to lower the solvent content of the paints used in coil-coating. It is however more a continuous improvement

than a real breakthrough: there are only a handful of cases where it has been possible to cut the solvent content down to a value below 30% without a significant change of the properties/cost of the final product.

- Health and safety requirements for VOC levels in paint-handling areas.
- Theoretically, there is also a driving force related to the reduced solvent loads within the ovens which may allow higher line speeds, increased efficiency, reduced energy demand. However, in practice this is not true for coil-coating because of the expected properties of the coil-coated products.

~~IED.~~

#### **Example plants**

No data submitted.

#### **Reference literature**

[13, DFIU and IFARE, 2002], [22, ECCA, 2004] [185, ECCA 2017]

#### **6.4.2.4 Water-based paint coatings**

See Section 17.7.2.2.

##### **Description**

Water-based paints contain water-dilutable or water-dispersible resins usually based on polyester, acrylic, melamine and epoxy resins. Most water dilutable paints currently available also contain up to 20 % of organic solvents as coalescents.

##### **Technical description**

See Section 17.7.2.2. Water-based paint systems for coil coating are usually one-component paints. They are mainly based on polyester, acrylic, melamine and epoxy resin. Water-based paint systems normally have a water content of 10–65 wt-% and often also contain < 3–20 % organic solvents as a coalescent and for improvement of the properties of the wet film layer.

##### **Achieved environmental benefits**

See Section 17.7.2.2.

~~Elimination or important reduction in solvent emissions from coating systems. The application of water based coating systems represents a possibility for abatement of VOC emissions on principle.~~

##### **Cross-media effects**

See Section 17.7.2.2.

~~Due to the solvent content, around 20 %, and the high annual load, a waste gas treatment is needed with the related high energy consumption. Thermal WGT may require additional NG to achieve emission levels.~~

Water has a higher energy of vaporisation than organic solvents, so water-based coatings in coil coating may require greater energy inputs in the curing ovens, **TWG: Please confirm** and, unless they are totally solvent free, will still require exhaust abatement where again a high gas consumption could result.

##### **Environmental performance and operational data**

See Section 17.7.2.2.

~~Water based systems usually use amines for pH stabilisation. Experiments with these amines in one company have encountered major problems with these amines concerning employee protection~~

~~Water based systems can present difficulties in cleaning operations on the coater equipment, demanding more powerful cleaning agents than solvent based coatings.~~

~~With water based systems, there may be problems with corrosion in storage, pumping and application equipment, and in the ovens and exhaust ducting.~~

#### **Technical considerations relevant to applicability**

This is a niche coating used in small quantities for coil coatings, as water-based paint systems are not applicable for a wide range of uses. Currently, processed water-based paints do not exceed 0.2 % of the total paint consumption in coil coating processes in Western Europe. If water-based coatings are used, the application is mostly limited to primers and backing or ~~ground~~ base coating. Water-based coating systems have been used on some coil coating lines for many years, but they are not applicable for a wide range of end use specifications. They may be used on lines dedicated to a limited product range where specific formulation development satisfies the performance demands.

#### **Economics**

See Section 17.7.2.2.

~~Water based coating systems do not cause major cost increases. Replacement of equipment with stainless steel alternatives to counter corrosion is typically more expensive.~~

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

A plant in Austria.

#### **Reference literature**

[13, DFIU and IFARE, 2002] [22, ECCA, 2004] [38, TWG, 2004] [185, ECCA 2017]

### **6.4.2.5 Powder coatings**

#### **Description**

See Section 17.7.2.8.

#### **Technical description**

~~These coating systems are finely divided powder coatings, generally based on polyester resins. The powder particles are normally applied by electrostatic charging in spray guns or a cloud chamber and are then attracted to the earthed metal strip as it passes. Application is generally carried out at one side of the strip with one layer with a typical layer thickness of 50 µm to 60 µm.~~

#### **Achieved environmental benefits**

See Section 17.7.2.8.

~~A complete elimination of solvent emissions from the coating system. There is a potential for reduced gas consumption, as exhaust incineration may no longer be needed.~~

#### **Environmental performance and operational data**

The chemical pretreatment of the surface is similar to the application of solvent-based products. Drying or curing is typically carried out by a combination of infrared and circulating hot air, or with NIR or induction ovens. Object temperatures of 180–250 °C are achieved. The curing process is typically completed within 1.5–2 minutes. Application is generally carried out on one side of the strip with one layer with a typical layer thickness of 50–60 µm.

#### **Cross-media effects**

~~Film thickness limitations will increase the quantities of coating materials used. The development in the curing oven of reaction products emitting odour, during the fusion and reaction of the powder could make the application of an abatement technique necessary anyway.~~

No information provided

### **Technical considerations relevant to applicability**

There is a severe reduction in line speed for powder application, melting, fusion, flow and cure, as most coil coating lines run at a far higher speed than that achieved using powder technologies (typically 150 m/min for recent coil coating lines versus 20m/min for powder coating). Powder coating is therefore limited to low line speeds with some specific products, as there is also a very limited range of powder coating qualities that can be applied and cured in these short times.

~~There is a severe reduction in line speed for powder application, melting, fusion, flow and cure (limited to 15 m/min)..~~

Current technology cannot yet achieve uniformity in powder coatings at less than 30 microns film thickness. Together, these limitations mean that a changeover to powder coatings is not feasible for conventional installations at present. This technique is especially used by the construction sector, e.g. for flat panels, window frames, sanitary cabins and by the sheet metal processing industry (computer enclosures and others). It is also used in small volume niche products. Two-sided powder coating on a coil coating line is still problematic.

### **Economics**

Production costs are higher compared to liquid coating processes due to the severe speed restrictions and the difficulty in controlling the applied film thickness.

### **Driving force for implementation**

No information provided

### **Example plants**

There are a few full width powder coating installations in Europe for aluminium and steel coils.

### **Reference literature**

[13, DFIU and IFARE, 2002] [22, ECCA, 2004] [78, TWG, 2005]

## **6.4.2.6 Laminate film coatings**

### **Description .**

Polymer films applied onto the coil in order to give aesthetic or functional properties

### **Technical description**

For some specific end uses solvent-free, solid polymer films are applied to coil coating plants. These films may be based on a number of polymers including:

- PVC (polyvinyl chloride);
- PVF (polyvinyl fluoride);
- PET (polyethylene terephthalate);
- acrylics;
- polypropylene.

In some cases, the films are coloured or opaque and may be decorated with printed patterns. In others, they are clear films offering specific properties of hardness, stain resistance, etc. In almost every case, the film is applied over a liquid paint base coat or adhesive layer. Specific equipment is needed to laminate the plastic film onto the strip.

### **Environmental performance and operational data**

Films are applied by a pressure roll onto a preheated coating of appropriate base coat/adhesive, usually immediately on exit from the curing oven.



The relative environmental performance (versus standard paint) depends on the final composition of the coating system. If the film is used instead of a normal paint layer, glued onto the web with preheated adhesive, there is no evidence of a better environmental performance than liquid coil coating. When the laminated film is applied on the top of a paint system, then the overall raw material and energy consumption can be significantly lower.

*TWG: Please clarify the following two statements:*

There is no difference between coating with paint or applying a laminate with an adhesive, as normally adhesives have higher content of solvent than in paints.

Elimination of solvent from one layer in the coating system preventing the emissions of solvent to the air.

Comparison of a standard paint (primer and finish coating) and a foil coating shows a longer life for the foil coating than the paint coating because the film coating is normally thicker than the paint coating and therefore more resistant.

#### **Cross-media effects**

The polymer films are produced off site by an extrusion or calendaring process. The ordered width rarely matches the exact dimensions of the coils to laminate. The excess film is side trimmed and is a process waste.

#### **Technical considerations relevant to applicability**

Generally used for very specific end use properties. Laminate film coatings cannot compete with liquid coil coating for all standard cases.

#### **Economics** ~~More expensive than conventional liquid coatings.~~

The process needs specific equipment. If this equipment was not installed at the time the line was built, it can be difficult and expensive to retrofit.

Laminated films are more expensive than conventional liquid coatings. The process is only of interest when some specific function is required that is difficult or impossible to achieve with liquid coating.

#### **Driving force for implementation**

Product specifications and innovation.

The process offers the possibility to deliver some niche products for specific purposes.

#### **Example plants**

No data submitted.

#### **Reference literature**

[22, ECCA, 2004] [185, ECCA 2017]

#### 6.4.2.7 Radiation curing coatings (Radcure)

See Section 17.8.5

### 6.4.3 Coating application techniques and equipment

#### 6.4.3.1 'Spray, squeegee and rinse' application of conversion coatings

##### Description

Conventional ~~pretreatment~~ application ~~refers to products~~ of pretreatments is by spray and dip processes for all substrates. After spray application, the excess liquid is removed from the coil by a squeegee roller to remove carry-over, followed by a rinse step.

##### Technical description

Spray application is carried out in closed cabinets. In all cases, the use of a further water rinsing step is absolutely necessary.

Iron phosphating products for cold rolled steel strips are used together with a post rinse, previously containing chromate, but chromate (Cr(VI)) -free rinses are becoming the norm. The alkaline conversion coatings (cobalt-based or cobalt-free), in combination with post rinses ~~containing chromate~~, provide excellent paint adhesion and corrosion protection on zinc or zinc-alloy coated substrates. Both technologies have been used for many years in coil coating lines all over the world.

~~Moreover, chromating of zinc coated and aluminium strips is a common process for conventional surface treatment.~~

##### Achieved environmental benefits

No data submitted.

##### Environmental performance and operational data ~~High durability is achieved.~~

The process temperature is between room temperature and about 70 °C. The spray pressure applied is between 0.5 and 2 bar.

##### Cross-media effects

This technique causes a high consumption of surface treatment chemicals. There is a high drag-out causing polluted rinsing water for subsequent waste water treatment and additional waste.

Large volumes of water are needed for this process. It is possible to significantly lower these volumes with an appropriate design of the rinsing step (see example of cascade rinsing in Section 17.4.1.5) but water consumption will never fall to zero because the rinsing baths need to run with an overflow. Moreover, there is a high drag-out of the chemicals used in the conversion step and this pollutes rinsing water, requiring subsequent waste water treatment and creating additional waste.

##### Technical considerations relevant to applicability

This is a well-known and common application technology, however it requires a high demand for chemical process control. Such a process is generally highly sensitive to temperature, chemicals concentration, cleanliness of the surface and conversion time. The deposition rate is therefore relatively difficult to adjust perfectly.

The maintenance of these closed cabinets is easier than a chemcoater.

##### Economics ~~No data submitted.~~

The erection of such a surface treatment section requires a large amount of space. In most cases, cleaning and conversion baths are horizontal, which means that more than 50 m<sup>3</sup> is needed for a coil coating line running at a normal speed.

It is also possible to set up vertical baths but this makes the process control more difficult than with a horizontal system. Such equipment is then relatively cheap (compared to a chemcoater) but it can only be erected if the necessary space is available.

In terms of operating costs, waste water needs should be considered and this is generally a hidden cost because most water treatment stations collect water from different industrial processes and its global cost is rarely broken down.

#### **Driving force for implementation**

It is a well-known and safe technology.

#### **Example plants**

No data submitted.

#### **Reference literature**

[22, ECCA, 2004] [185, ECCA 2017]

### **6.4.3.2 'No rinse' or 'dry in place' application of conversion coatings**

#### **Description**

The 'no rinse' or 'dry in place' technology used to apply conversion coatings by roller coater (chemcoater) or squeegee rollers which does not require a further water rinse.

#### **Technical description**

The 'no rinse' or 'dry in place' technology for applying conversion coatings does not require a further water rinse. It applies the pretreatment products by roller coater, chemcoater or squeegee rollers to the strip surface. Because it avoids aerosol formation, no pollutant can be measured in the air. Without any rinsing, the wet film is dried in place, using IR radiation or convection heat and painted directly afterwards. This kind of process does not limit the line speed in the pretreatment section (no reaction time), needs no rinse stages after the pretreatment section, and generates extremely low levels of waste water. Another advantage, compared to the conventional rinse process products, is its suitability for multi-metal pretreatment.

#### **Achieved environmental benefits**

The water consumption is significantly lower than with a spray, squeegee or rinse system because there is no overflow. Chemicals are also consumed in the exact quantity required, avoiding over-consumption. The consumption of water and chemicals in a spray, squeegee or rinse surface treatment system is therefore significantly higher than the dry in place system.

Because of the low amount of waste water and of the low concentration of pollutants, no water treatment station is necessary.

Small droplets or vapours of the chemicals used are generally harmful and alternative surface treatment methods can generally not be used without air extraction to remove mist and vapours from above the baths. This extracted air is then either released to the atmosphere (thus generating air pollution) or goes to the incinerator (and then needs extra energy for burning cold moisturised air). With the dry in place technique, there are no mists and vapours. It means that there is no air pollution or requirement for extra energy for treatment of polluted air.

~~This technique generally produces waste in very small volumes, whereas the technique above (see Section) produces larger volumes of waste. Also, the chemical consumption is much lower in comparison to the technique because application efficiency and material usage approaches 100 %. This makes overflow to waste water superfluous as also any waste gas abatement technique.~~

#### **Environmental performance and operational data**

Water quality in the last rinse of the cleaning section prior to the no-rinse conversion coating application must be strongly monitored by conductivity measurements.

The applied wet layer thickness depends on used application technique and concentration of used chemical. Drying takes place immediately after applying the conversion coating and it takes a short time, with infrared or hot air dryers.

~~Generally, the conversion coating contains chrome from which the treatment involves reducing the oxidation state of the chromium from (VI) to (III), thus making it less hazardous prior to disposal~~

### **Cross-media effects**

Dryers require electrical energy or natural gas. The energy consumption is slightly higher than with alternative methods for surface treatment.

Water quality in the last rinse prior to the no-rinse conversion coating application must be strongly monitored by conductivity measurements.

### **Applicability**

This application technology is currently well known and approved, and widely used across Europe.

### **Economics**

There is a significant CAPEX for the erection of a surface treatment section. On an existing line, if the existing surface treatment is a spray, squeegee, rinse system, then the space and water treatment stations are generally already available and the investment cost is then a hurdle.

On a new line, the overall cost of a dry in place system is equivalent to the cost of spray, squeegee, rinse system because of the lower space requirement and because no water treatment station is needed.

~~There are investment costs involved for the application unit. Savings are made because of the low consumption of surface treatment chemicals and much less waste water has to be treated.~~

### **Driving force for implementation**

- Low consumption of surface treatment chemicals and very low volumes of waste;
- Lower risk of exposure to chemicals for the workers.

### **Example plants**

Widely used across Europe.

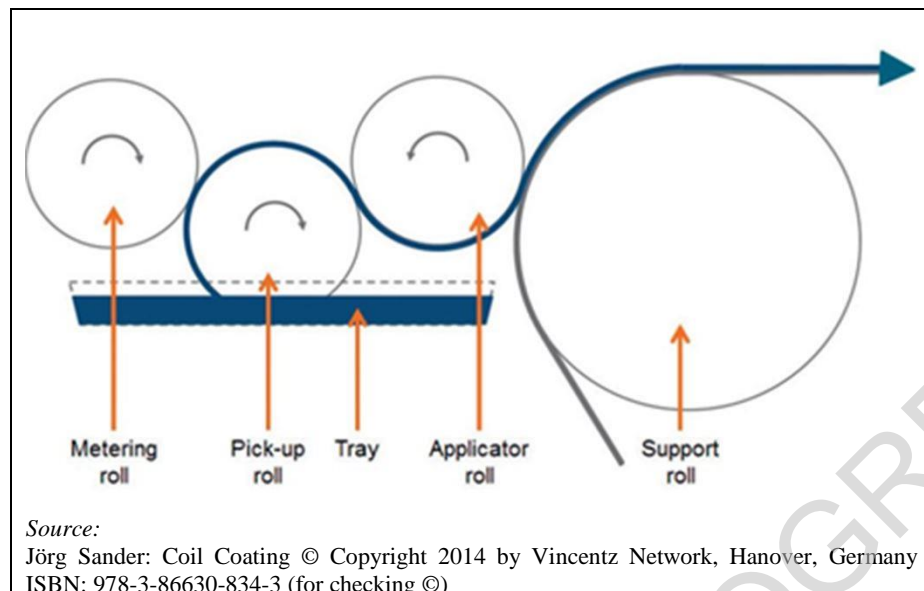
### **Reference literature**

[22, ECCA, 2004] [185, ECCA 2017]

### **6.4.3.3 Roller coating of paints**

#### **Description**

~~The roller coating process dominates the application of liquid coatings on modern coating lines. A train of two or three rollers serves to 'pick up', 'meter' and 'apply' the coating at high speed onto the moving strip.~~



**Figure 6.15: Schematic of a three-roller paint coater**

### Technical description

There are different types of coater in use e.g. with a horizontal or vertical strip path or with or without a counter roll. Roller directions, rotation speeds, spacings and pressures are controlled to set the film thickness and to optimise the transfer properties and flow out of the wet coating.

Roller coating is an old technology (as old as the coil-coating industry itself) but is constantly being improved, mainly with the objective of reaching the targeted thickness more rapidly, more evenly and more accurately.

### Achieved environmental benefits

Very high transfer efficiency, approaching 100 % thus achieving a high material efficiency for paint solids and solvents, and minimal waste of materials.

### Environmental performance and operational data

Very high transfer efficiency due to:

- better mechanical precision in the coaters;
- better temperature management on the rolls and in the overall paint flow;
- progress in automation and the availability of some wet thickness gauges that give a fast and accurate thickness measurement which in return allow a closed-loop regulation (or at least a fast reaction from the operator).

The only loss is associated with material remaining in containers and pipework at the end of a product 'run'. This is normally drained back into the original container for use on later occasions. After draining, final traces of the coating are cleaned up from the rollers and the equipment (rollers, paint tube) with appropriate method.

The coaters are normally housed in enclosures to minimise the release of organic solvent vapours to the factory area. The coating housings are vented to the outside of the building with flowrates designed to maintain satisfactory working conditions at all times for the operators within the coating house. Beyond the positive consequences for health and safety, it also makes it possible to extract VOC-containing air from the working zone (see Section 17.10.2.2).

Most of the coatings are diluted with organic solvents to get the right surface and to reach the correct thickness of the paint. The solvents are vaporised in the oven and extracted to thermal WGT.

Cleaning a roller coater is generally difficult to do with a 100% safe method and without using a significant amount of solvent. Today, manual cleaning is still the most common method but not the safest one.

The application rollers generally have a thick elastomeric, polyurethane coating which may become damaged, requiring refacing on a lathe. Ultimately, the coating must be renewed by a specialist contractor. The pick-up and metering rolls are normally steel and less prone to damage.

The paint lost because of out-of-range of thickness or because of transitory step in between two orders is then minimised. *TWG to clarify: information from TWG but context not clear*

**Cross-media effects** ~~No data submitted.~~

The safest cleaning methods tend use more solvent.

### **Technical considerations relevant to applicability**

Used in virtually all coil coating lines using liquid paints. The method is of course not suitable for powder coating. In the case of paints with a high viscosity (high solid contents, for example), it is necessary either to have a more sophisticated roller coater and/or to accept higher paint thickness.

### **Economics**

This coating method is relatively expensive, with high initial costs. Depending on whether one side or two sides are painted, on the kind of products (and then on the configuration of the roller coater), and on the level of automation, the CAPEX can vary significantly. In most cases, in coil coating, the cost will exceed EUR 1 million and can be far higher.

### **Driving force for implementation:**

Very high transfer efficiency and, therefore, minimal waste of materials. Typically, a roller coater is theoretically able to coat 20 +/- 1 µm dry thickness in the ideal cases; in the case of flat surfaces, it is far better than other coating methods. The high investment cost is then generally rapidly balanced by significantly lower operating costs.

### **Example plants**

Established as industry standard and widely used.

### **Reference literature**

[22, ECCA, 2004] [185, ECCA 2017]

#### **6.4.3.4 Cleaning of application equipment**

##### **Description**

In coil coating plants, there are two recognised methods for the cleaning of machine parts and equipment:

- all cleaning takes place *in situ*, i.e. within the coating house/room;
- *in situ* cleaning for fixed equipment, with moveable items such as paint trays pumps and stirrers removed to an ancillary cleaning station as detailed above.

Wipes impregnated with solvents are used when manual cleaning of the plant and equipment takes place. Disposable dirty wipes are retained in sealed containers and disposed of usually by incineration. Reusable dirty wipes are also retained in sealed containers and are usually laundered.

##### **Achieved environmental benefits**

Localised extraction to ovens/abatement reduces fugitive solvent emissions.

**Cross-media effects**

No data submitted.

**Operational data**

Some, but not all, coating houses are equipped with localised extraction, which is directed into the oven/waste gas treatment system, with the balance vented to the air. Where an ancillary cleaning unit is used, extraction is generally abated. In other instances, all coating room air is vented directly to the air, as it is widely considered that the installation of abatement equipment is not a practical option, as air volumes for occupational health reasons, are high with low emission concentrations. Compared with emissions from dryers/ovens, emissions from coating houses are considered to be insignificant.

**Applicability**

The practicality of the retrofitting of localised extraction in coating rooms will be dependent upon the age, design and capacity of the combined curing (drying) and abatement equipment.

**Economics**

Costs will depend on the existing extraction system and on the capacity of the waste gas treatment technique. Retrofit might, therefore, be very expensive.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[22, ECCA, 2004]

**Application of conversion coatings**

~~Hexavalent chromium conversion coatings and associated techniques are also discussed in the STM BREF [59, EIPPCB, 2006].~~

*Moved to 6.4.3*

**6.4.4 Drying****6.4.4.1 Convection drying or curing**

**Proposed for deletion - TWG please confirm that this is still a BAT candidate**

~~For a general description see Section 0.~~ Gas fired forced air recirculation ovens are commonly applied at temperatures of around 350 °C; the waste gas is extracted and routed to the abatement plant. Use of heat exchangers allows preheating of the air for the oven input to a maximum temperature of about 400 °C.

[22, ECCA, 2004] [38, TWG, 2004]

**6.4.4.2 Radiation curing processes**

For a general description, see Section 17.8.5. No commercial application is known for coil coating applications, but see Emerging techniques, Section 19.14.2.

[22, ECCA, 2004]

## **6.4.5 Waste gas treatment**

### **6.4.5.1 Air extraction from conversion coatings station**

When conversion coatings containing chromium are applied (see Sections 0 and 0), the mist arising from the spray application and drying of the conversion coating are extracted and routed to a waste gas treatment system, such as a wet scrubber (see Section 17.10.4.1). See the STM BREF for details of the techniques and BAT.

[78, TWG, 2005]

### **6.4.5.2 Air seals on the entrance and the exit of the ovens/dryers**

For a general description, see Section 17.10.2.5. This technique is commonly applied in the coil coating industry.

[22, ECCA, 2004], [38, TWG, 2004]

### **6.4.5.3 Negative pressure in drying**

For a general description, see Section 17.10.2.5. This technique is commonly applied in the coil coating industry.

[13, DFIU and IFARE, 2002] [22, ECCA, 2004], [38, TWG, 2004]

### **6.4.5.4 Air extraction from coating preparation**

#### **Description**

Before use, paint is prepared in an enclosed room referred to as a paint kitchen. The drum is opened and stirred, which generates solvent evaporation. Usually, air is extracted from the room to the oven/waste gas treatment system.

#### **Technical description**

For a general description, see Section 17.10.2.3.

Coatings are prepared by stirring to ensure that any settled pigments are thoroughly mixed and that the coating is at the correct viscosity for application. Solvent-based raw materials are mixed, e.g. for achieving a certain viscosity or colour. In coil coating plants, the mixing and stirring of paint takes place either in the coating house/room or in a separate room often referred to as a paint kitchen. Commonly, coating houses are equipped with localised extraction. The extracted air is directed into the oven/waste gas treatment system, with the balance vented to the air.

#### **Achieved environmental benefits**

Reduction of VOC fugitive emissions from the coating house/ room/ paint kitchen (but overall, remain unabated). Where the VOC containing air flow is channelled to an abatement system, the overall VOC emissions to air is lowered.

#### **Environmental performance and operational data**

As for occupational health reasons, air volumes are high with low emission concentrations, in some installations all the coating room air is vented directly to the air. It is widely considered that installing abatement equipment is not a practical option in these cases.

Compared with emissions from ovens/dryers, emissions from paint kitchens are considered to be insignificant. (However, see Section 17.10.2.3)



**Cross-media effects**

To achieve safe working conditions and a low VOC content of the airstream, large quantities of energy (e.g. gas) are needed for WG treatment.

**Technical considerations relevant to applicability**

The practicality of the retrofitting of localised extraction in coating rooms will be dependent on the age, design and capacity of the combined curing (drying) and abatement equipment.

**Economics**

On existing coil coating lines where additional abatement equipment capacity is required, cost for retrofitting may be high.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[22, ECCA, 2004], [38, TWG, 2004][175, ECCA 2017]

**6.4.5.5 Air extraction from the paint application station**

For a general description, see Section 17.10.2.1.

**Description**

The paint application station is enclosed (see Section 17.10.2.1), and part or all of the extracted air is drawn into the ovens, and hence to an exhaust abatement system.

**Achieved environmental benefits**

About 8 % of the processed solvents are released as VOC emissions in the paint application booths and, by applying this technique, are extracted and treated.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

This technique is commonly applied.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

Widely applied

**Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [22, ECCA, 2004]

#### 6.4.5.6 Air extraction from the oven/dryer

For a general description, see Section 17.10.2.6.

##### **Description**

The driers and ovens are equipped with an air extraction system routing the solvent emissions to the waste gas treatment

##### **Technical description**

Drying/curing of the coil coating is done in ovens/dryers which are connected to abatement equipment, e.g. thermal oxidiser (see Section 17.10.5.2).

In the case of a coil-coating oven, the management of the solvent concentration is generally based on some FID measurements within the oven, in the zone where it appears relevant (i.e. the zone where it is most likely to have the highest concentration). The oven is then run in such a way that air is used with the minimum required flow to keep at acceptable levels for avoiding explosion risk. The solvent concentration in the extracted air is then as high as possible as long as it is safe.

The European Standard EN 1539:2015 defines the admissible operating ranges with respect to the admissible drying temperature and the maximum admissible concentration of released flammable substances.

##### **Achieved environmental benefits**

Most solvents are released during the step of curing / drying. Having an efficient extraction of the air from the oven and an efficient oxidization later is the best way of significantly lowering overall emissions. In the case of coil coating, the extraction and incineration explains why VOC content keeps at very low value instead of the huge solvent consumption.

The use of FID for optimizing the air flow in the oven makes it possible to lower the overall energy needed in the drying / curing step.

The fugitive solvent emissions are reduced to the maximum extent having an efficient extraction system.

~~Up to 2 % of the processed solvents are released as VOC emissions into the ovens/dryers. These are collected and transferred to an abatement plant.~~

##### **Environmental performance and operational information**

The quality control of the prepainted product ensures that all solvents are released out of the paint ( $O_3=0$ ) and all solvents from the paints are then vaporized in the oven. An efficient air extraction system makes it possible to capture most of these solvents to flow them out to the incinerator (the curing step doesn't significantly increase  $O_4$ ). A small amount of solvents can exit the oven with the strip (boundary air layer close to the strip), so other techniques are often used at the same time to stop or capture this small flow.

The VOC content in the ovens of an example plant is in the range of 8.75 - 9.3 g/m<sup>3</sup>, which is around 22 % of the LEL (40 g/m<sup>3</sup>). The flow of fumes is continuously measured and the concentration of VOC in the oven/drier can also be measured, as it is turning common today for various reasons (for safety, for a lower energy consumption and for a lower environmental impact).

##### **Cross-media effects**

~~No data submitted.~~

Extraction requires energy, primarily electrical energy for the operation of extraction fan. Noise levels might increase.

##### **Technical considerations relevant to applicability**

This is commonly applied.

**Economics**

No data submitted.

**Driving force for implementation**

~~No data submitted.~~

Workplace health and safety.

According to the standard EN 1539:2015, the dryers shall be equipped with a forced ventilation system to ensure the maximum admissible concentration for the maximum admissible quantity or the maximum admissible throughput of flammable substances.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [22, ECCA, 2004] [38, TWG, 2004] [175, ECCA 2017]

**6.4.5.7 Air extraction from the cooling zone****Description**

After the curing step, it is necessary to cool the strip down, generally with water sprays. In this zone, fumes or vapours can be extracted to further abatement or to a vent stack.

**Technical description**

For a general description, see Section 17.10.2.

The strip temperature at the exit of the oven lies in the range of 200-260°C and requires cooling down before, either coating a second layer (for the primary oven) or entering the accumulator tower before recoiling. This step needs to be rather short because the longer the cooling time, the more space needed. Such high cooling rates are achieved with sprays of cold water onto the strip or dipping the strip into a cold-water bath.

A cooling section is then generally designed in such a way that the sprays (or the water bath) are in an enclosed zone. This makes it easy to extract air from the cooling zone. It is then possible to channel the extracted air flow to any air treatment device.

~~After curing, the strip is typically cooled by water sprays. The area where the strip is cooled is enclosed and fitted with a local exhaust ventilator. The waste gas containing solvent is subsequently routed to abatement equipment, e.g. thermal oxidiser. The water is cooled and recycled.~~

**Achieved environmental benefits**

There is no environmental benefit with such a technique in the case of coil-coating.

- the quantity of VOCs at the exit of a coil-coating oven is too low to consider capturing and abating these VOCs as an environmental benefit.
- there is no direct impact of air extraction on the amount of water or on its quality.

Main driver for this technique is more related to health & safety and working conditions and not an environmental benefit.

~~Approximately 2 % or less of the processed solvents are released as VOC emissions in the cooling zone. Due to ovens operating under negative pressure solvent emissions are minimised.~~

**Environmental performance and operational information**

Using an air extractor makes it possible to better identify the nature and the concentration of pollutants emitted from the cooling section in cases where it makes sense to do so. Without air extraction, these pollutants would be part of the fugitive emissions

~~In some instances, the first step strip cooling is achieved using high volumes of blown air.~~

### **Cross-media effects**

If the extracted air goes directly to the incinerator, the energy consumption for treating this extra air-flow is relatively high because air temperature is low, because air does not contain solvent (i.e. there is little available fuel in the extracted air) and the extracted air contains water droplets that require energy to vaporise. (i.e. latent heat is needed to vaporise water).

The overall efficiency of the oxidizer can also be lowered by the addition of air extracted from the cooling zone because the global mixture would deviate from optimum concentration and composition for an efficient oxidizing condition. Treating the extracted air in an oxidiser may significantly compromise the efficiency of the oxidiser resulting in higher VOC emissions and significantly higher energy consumption

~~The energy consumption to treat air containing low solvent concentrations will be significant.~~

### **Technical considerations relevant to applicability**

All coil-coating lines are equipped with a cooling section and extracting air from cooling sections is quite common.

~~Extraction of air containing solvent from this activity is commonly applied. However, it is usually not treated in an abatement system as it implies high gas consumption. This energy is required to treat large volumes of very low concentration and low temperature extracted air.~~

~~Water cooling is commonly applied in the coil coating industry. Air cooling is applied in some special cases depending on the market and the quality of the products (but commonly in the aluminium coil coating industry).~~

### **Economics**

High costs are involved.

### **Driving force for implementation**

~~No data submitted.~~

Depending on how the line is designed, it is likely that residual fumes or vapours at the exit of the ovens get trapped within the building if nothing is done to remove them. This accumulation over time makes the working area uncomfortable for workers. Most operators extract air from the cooling zone to improve the working conditions of operators.

### **Example plants**

No data submitted.

### **Reference literature**

[13, DFIU and IFARE, 2002] [22, ECCA, 2004], [38, TWG, 2004] [175, ECCA 2017]

#### **6.4.5.8 Recuperative thermal oxidation**

For a general description, see Section 17.10.5.3. Recuperative thermal oxidation has been commonly applied in the coil coating industry in Europe since the 1970s.

[22, ECCA, 2004]

#### **6.4.5.9 Regenerative thermal oxidation – dual bed**

For a general description, see Section 17.10.5.4. This technique has been commonly applied in the coil coating industry in Europe since the end of the 1990s.

[22, ECCA, 2004]

## 6.4.6 Waste water treatment

### 6.4.6.1 Treatment of rinse water before discharge

#### Description

Process waters are usually treated in a waste water treatment plant with a sequence of process steps. Dissolved metals in rinse water are precipitated, e.g. by using lime or sodium hydroxide (see Section 6.4.6.3). The liquor is subsequently processed through a filter press to separate the solids from the liquids. Some chemicals are most effectively managed by treating them separately before mixing them with other effluents.

#### Achieved environmental benefits

For some substances, contaminant treatment and removal is only possible after separate treatment. Use of waste alkali solutions (such as degreasers) to neutralise waste acid solutions saving chemicals.

#### Cross-media effects

Will be case-dependent.

#### Operational data

No data submitted.

#### Applicability

Consideration should be given at every process discharge point as to whether treatment is better carried out on the separated stream, before mixing flows for subsequent treatment.

When using waste alkali flows to neutralise waste acids, additional chemicals may be required to achieve a suitable pH for discharge through a flocculation system.

#### Economics

Capital and treatment costs may be significantly reduced by treating individual waste water streams separately.

#### Driving force for implementation

The specific process chemistry will dictate which chemicals may require separation. Separate treatment streams may be more efficient and cost-effective.

#### Example plants

No data submitted.

#### Reference literature

[22, ECCA, 2004] [59, EIPPCB, 2006]

### 6.4.6.2 Treatment of waste water containing chromate

#### Description

Hexavalent chromium compounds (chromates or dichromate) are difficult to precipitate and are normally reduced to trivalent chromium, which is subsequently precipitated as chromium (III) hydroxide on neutralisation. The reduction is made at pH values under 2.5. The most common reducing agent is sodium hydrogen sulphite (bisulphite).

#### Achieved environmental benefits

Reduction and removal of chromium (VI). Commonly, values of  $< 0.1$  mg Cr(VI)/l are achieved.

### **Cross-media effects**

Care should be taken with sodium hydrogen sulphite (bisulphite), as SO<sub>x</sub> fumes are formed. Workspace ventilation may be required.

### **Operational data**

If only a small amount of chromium (VI) is present at high pH values, the reaction can also be carried out in the alkaline area with sodium dithionite or iron (II) compounds, whereby the formation of salt by acidifying is not necessary if using iron (II) compounds.

### **Applicability**

This technique is widely used. Flows containing chromate must be pretreated separately before being mixed together or mixed with other waste waters. The chromate reduction takes place at pH values < 2.5. In order to limit the use of additional chemicals, acid waste water can be neutralised with alkaline waste water.

### **Economics**

No data submitted.

### **Driving force for implementation**

Water pollution protection legislation.

### **Example plants**

No data submitted.

### **Reference literature**

[22, ECCA, 2004] [59, EIPPCB, 2006]

## **6.4.6.3 Hydroxide precipitation**

### **Description**

The removal of the transition metals is made via neutralisation then precipitation at pH values of 9–11. A water-solid mixture results from the precipitation. Lower emission values can be achieved if fine filtration is also used.

### **Achieved environmental benefits**

Removal of transition metals from effluent.

### **Cross-media effects**

No data submitted.

### **Operational data**

Settlement tanks need space and may be costly to install. Caustic solution usually precipitates the heavy metals as hydroxides or phosphates. If several metals exist in the effluent at the same time, the precipitation of any metal that is more difficult to precipitate is facilitated.

The solubility of the metals increases with increased neutral salt concentrations. The metals partly precipitate in very fine particles, therefore the addition of flocculating agents (iron (III) chloride, lime) and/or flocculants (polyelectrolyte) are necessary for better separation and filtration.

### **Applicability**

This technique is widely used.

### **Economics**

Investment costs might be significant.

**Driving force for implementation**

Water pollution protection legislation.

**Example plants**

No data submitted.

**Reference literature**

[22, ECCA, 2004] [59, EIPPCB, 2006]

WORKING DRAFT IN PROGRESS

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## 7 MANUFACTURE OF ADHESIVE TAPE

[14, DFIU and IFARE, 2002] [38, TWG, 2004, 78, TWG, 2005] [132, AFERA, 2005]

### 7.1 General information on the manufacture of adhesive tape

*TWG please provide updated information*

Adhesive tapes are used in many different industries such as packaging, vehicle production, electrical equipment, construction, furniture and paper industries as well as for the do-it-yourself market. Each industry has a wide range of different requirements for product applications and properties that have to be met. In the vehicle industry for example, adhesive tapes are used for attachment of parts onto outer surfaces of car bodies, for abrasion protection, for caulking small openings, for wrapping cables, for masking during painting and for supporting functions during assembly.

Depending on the use, widely different requirements concerning product properties have to be met, such as adhesive strength, resistance against temperature, mechanical rigidity, tensile strength, shear adhesion, etc. VOC emissions in the production of adhesive tapes originate from the application of solvent-based adhesive systems and the application of auxiliary material containing solvent such as release agents and primers.

Due to the range of products and production techniques, installations usually specialise in certain types of products. Some installations specialise in using adhesive systems based on solvents. In these installations, significant amounts of VOC are used as solvents in the adhesive systems, in auxiliary materials such as release agents and primers and as cleaning agents. In most cases, the amount of solvents used exceeds the threshold of 200 t/yr.

In 2003, 45 installations in Europe produced about 3 300 million m<sup>2</sup> of these solvent-based adhesive tapes. They share a proportion of about 40 % in the total European adhesive tape production.

The other part of the European adhesive tape market is covered by product groups for other purposes or with other properties. They are produced in installations using adhesives based on hot melt, water-based dispersions and UV cross-linking adhesives. These installations use no or only very small amounts of VOC (usually for cleaning).

#### 7.1.1 Applications of pressure-sensitive adhesives

The selection of the solvent-based adhesive system depends on the technical application of the adhesive tapes. Table 7.1 gives an overview of different applications of adhesive tapes and the adhesives most commonly used.

Table 7.1: Applications of solvent-based pressure-sensitive adhesives for adhesive tapes

<b>Tape use</b>	<b>Application</b>	<b>Solvent-based pressure-sensitive adhesive</b>
Packaging	Adhesive labels, adhesive tapes for packaging	Natural rubber adhesives, (SB)
Automotive industry	Transfer adhesive tapes for decorative strips and flank protection strips, insulating slabs, assembly aids for wheel case covers and skirt side panels, adhesive tapes for winding wire harnesses	Natural rubber adhesives, esters of acrylic acid and acrylates
Construction industry	Foamed plastic adhesive tapes for sealing of windows, caulking of construction splices and expansion joints, carpeting adhesive tapes, etc.	Acrylate dispersions
Medicine	Medical tapes, adhesive plasters	Pure acrylates, polyacrylates
Furniture industry	Transfer adhesive tapes for mirrors, etc.	Acrylate adhesives
<i>Source: [14, DFIU and IFARE, 2002] [78, TWG, 2005]</i>		

## 7.2 Applied processes and techniques in adhesive tape manufacturing

### 7.2.1 Manufacturing of adhesive tapes

Solvent-based adhesive tapes consist of a substrate (backing), a coupling agent, a pressure-sensitive adhesive and releasing agents. The substrates used are: paper (widely used), fabrics, film, polyvinyl chloride foils, polyester, polyamide and aluminium. Products can be classified as transfer adhesive tapes (double-sided adhesive tapes), adhesive tapes for packaging purposes and adhesive tapes for coating purposes.

For the production of one-sided adhesive tapes, a pressure-sensitive adhesive is applied onto a substrate. Adhesion of the adhesive layer onto the substrate is improved by a physical surface preparation or an application of primers. For the production of double-sided adhesive tapes, a pressure-sensitive adhesive is applied onto both sides of the substrate. A releasing agent is applied onto one of the adhesive layers in order to avoid contact between the adhesive layers.

### 7.2.2 Materials for the production of adhesive tapes

Pressure-sensitive adhesives are organic compounds with a high self strength that have a high adhesive strength with different surfaces at the same time. Unlike other adhesive systems, the plastic adhesive film is also active in dry conditions. The adhesive shows visco-elastic behaviour and can be considered as a fluid with a very high viscosity. A classification of pressure-sensitive adhesives is shown in Table 7.2

**Table 7.2: Pressure-sensitive adhesives for the production of adhesive tapes**

Type of adhesive	Caoutchouc adhesive	Acrylate adhesive	Other pressure-sensitive adhesives
<b>Adhesives using solvents in production</b>			
Dissolution in organic solvents	Natural rubber (NR), butadiene styrene (SBR), styrene isoprene styrene block copolymer (SIS)	Pure acrylate, polyacrylate	Polyurethane, neoprene
<b>Adhesives not using solvents in production</b>			
Dispersion in water	Styrene butadiene styrene block copolymer (SBS), SBR latex, carboxylated (CSBR)	Pure acrylate, polyacrylate	Polyvinyl acetate, acrylate, ethylene vinyl acetate (EVA)
Hot melt	Styrene isoprene styrene block copolymer (SIS), butadiene styrene copolymer (SBR), styrene butadiene styrene block copolymer (SBS)	Polyacrylate	No application
Systems with 100 % solids content, radiation curing or as two part system. Natural rubber (NR), butadiene styrene copolymer (SBR), styrene isoprene styrene block copolymer (SIS) Pure acrylate, polyacrylate Polyurethane, polyester, two part polyurethane. <i>Source:</i> [14, DFIU and IFARE, 2002]			

#### Caoutchouc adhesives and resins

Caoutchouc adhesives that are technically processed are natural rubber (NR) and synthetic caoutchouc adhesives such as butadiene styrene (SBR), styrene isoprene styrene (SIS).

For the production of natural caoutchouc systems, caoutchouc is dissolved in organic solvents together with resins influencing cohesiveness and adhesion (so-called 'tackifiers'). Other additives, such as agents preventing the ageing processes are also added. These adhesives are mainly used for plasters, but also for double-sided adhesive tapes, adhesive tapes for packaging and coating adhesive tapes.

### **Acrylate adhesives**

Adhesive tapes are coated with acrylate adhesives especially for long-term or exterior use. Acrylate adhesives dominate the field of assembly application due to their higher thermal and chemical resistance as well as higher cohesion compared to caoutchouc adhesives. Solvent-based adhesives are dissolved in organic solvents (e.g. benzene, ethyl acetate or toluene). The solvent-based acrylate adhesives possess higher cohesiveness than water-based.

### **Other pressure-sensitive adhesives**

Thermoplastic elastomers, polyurethanes, as well as neoprene are also used for the production of adhesive tapes for special applications.

### **Solvents**

Solvents for pressure-sensitive adhesives are aromatic and aliphatic solvents with a boiling point of between 60 °C and 120 °C as well as mixtures of these components. Solvent proportions in adhesives ready for application range between 60 % and 75 %. High-solid systems with solid proportions over about 60 % are used in some cases.

### **Non-solvent adhesive tapes**

(Note the comments in Section 7.1 about installations using specific processes).

Synthetic caoutchoucs are applied as hot melts without solvents. For the production of such synthetic caoutchoucs, resins and other auxiliary materials are mixed in the melt, for example, in continuously working extruders and then coated as a melt. The thermoplastic behaviour of the compound is reversible.

Acrylate adhesives can also be applied as water-based dispersions, as 100 % solid systems (as UV cross-linking compounds).

### **Auxiliary materials**

Coupling agents allow a failure-free unwinding and restripping of the adhesive tape by increasing the adhesion between the pressure-sensitive adhesive and the substrate. The coupling can be realised by application of a primer layer. Primers are applied dissolved in organic solvents. Common low emission techniques for surface treatment are corona discharge, flammng and low pressure plasma surface preparation.

### **Releasing agents**

Releasing agents are used to prevent adhesion of the pressure-sensitive adhesive to the surface of the adhesive tape. Silicones are applied as releasing agents for acrylate adhesives and synthetic caoutchoucs. For natural caoutchouc adhesives, systems containing stearyl groups are also in use. Most of the releasing agents are applied as solutions.

### **Impregnating agents**

Impregnating agents are applied for surface refinement of smooth, absorbent papers in order to increase the wet strength and mechanical rigidity. For this process, polymer dispersions containing water are used based on SBR acrylate, acrylate as well as acrylate-natural caoutchouc systems for special applications.

### **Cleaning agents**

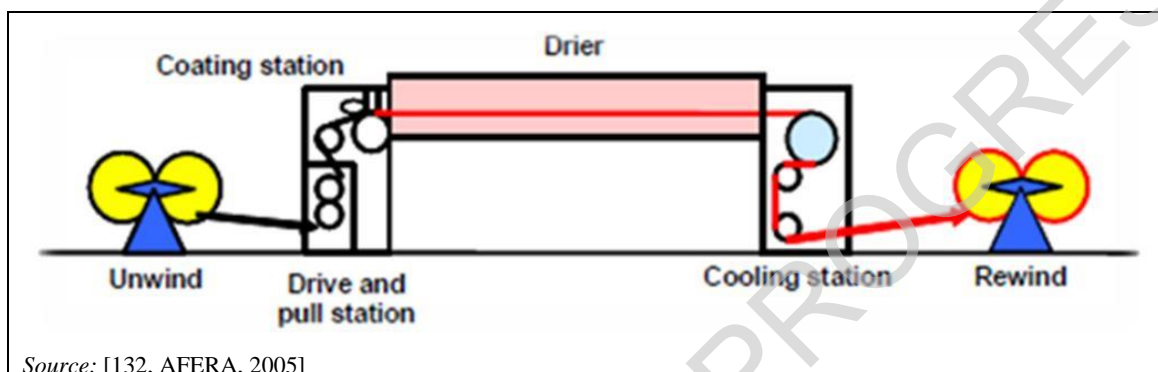
Usually, the same solvents are used for the different cleaning activities as are used in the adhesive systems, both for cleaning during production or for maintenance.

### 7.2.3 Production process of adhesive tapes

[78, TWG, 2005] [132, AFERA, 2005]

The production process can be subdivided into three main steps:

- coating: surface treatment of the substrate and the coating of the sheet-like substrate with the adhesive;
- drying (cross-linking) of the adhesive;
- winding.



Source: [132, AFERA, 2005]

**Figure 7.1:** Schematic layout of an adhesive tape production line

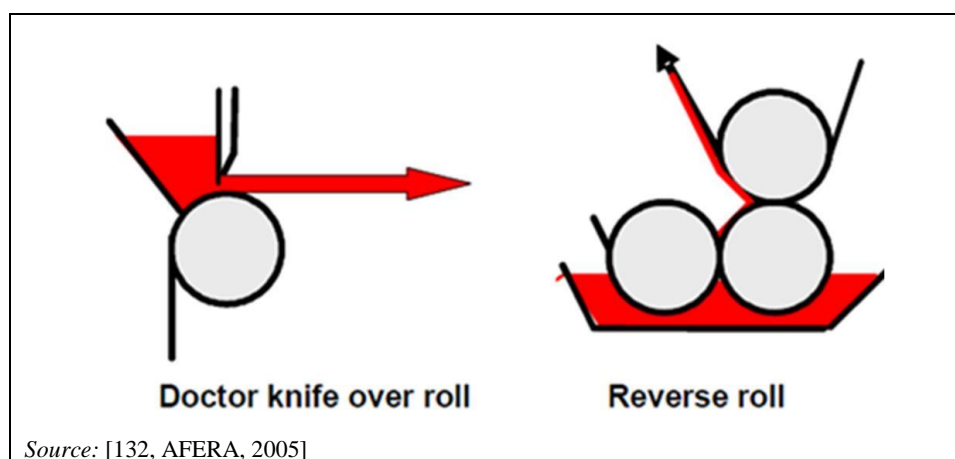
In addition, in (nearly) all solvent-based installations, the following auxiliary processes are installed:

- storing the adhesive components;
- adhesive mixing;
- waste gas treatment (of gas of the dryer);
- slitting the rewound tape.

This section describes the production steps of adhesive tape production which may have an impact on the environment.

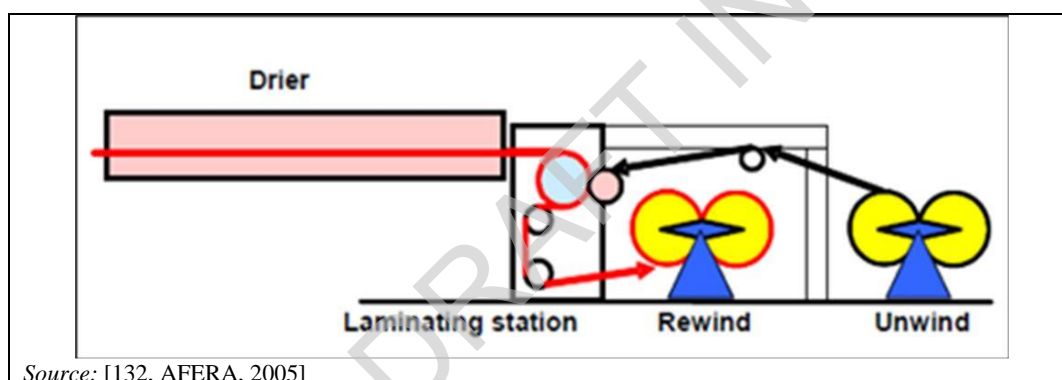
#### Coating

The application of a solvent-based pressure-sensitive adhesive can be carried out by different application techniques. Doctor knife systems or reverse-roll-coat systems as shown in Figure 7.2 are commonly used.



**Figure 7.2:** Different types of adhesive application units

The adhesive material can be applied directly onto the substrate. An alternative is the transfer technique, where the pressure-sensitive adhesive is dried onto the releasing material and cross-linked. Afterwards, the adhesive film is transferred onto the substrate by lamination; therefore the substrate has to be protected from damage during the drying process. Lamination can be carried out with coating directly to a transfer release liner and laminating with a backing as shown in Figure 7.3.



**Figure 7.3:** Lamination unit

The formulation of the adhesives is often situated close to the application process. Different mixing facilities are used for different types of adhesives:

- Granulated rubber, resins and other additives are put into a kneader filled with solvent. This is a slow batch processing for adhesives with a high viscosity.
- Granulated rubber, resins and other additives are put into a high speed mixer filled with solvent. The mixer has different mixing blades inside. This is a short batch process for a lower viscosity adhesive.
- Acrylic adhesive is made in batches in polymerisation stations. The reaction is based on a catalyst in the mixer, and is controlled by temperature and pressure.

Fugitive VOC emissions in these first steps of production may arise from the following processes or units:

- storing of solvents or pre-products containing solvent;
- formulation of the adhesives in the mixing units;
- leading the adhesives to the application machine;
- the application unit of the primer;

- the adhesives application unit.

Some of the fugitive emissions from these sources are captured and led to a waste gas treatment unit.

Waste results from mixed but used adhesives and from cleaning of the mixing facilities.

Normally there is no waste water from these processes.

### **Drying**

Solvent-based adhesives are dried thermally by convection dryers and infrared dryers. Any cross-linking can be carried out chemically or by UV radiation in order to improve technical properties. The air of the convection dryers is heated with gas, oil or steam via heat exchangers.

The main dryer equipment for solvent-based systems is differentiated by airflow and material transportation:

- in a tangential airflow dryer, the material is transported by rolls;
- in a single side dryer with nozzles over rolls, the material is transported by driven rolls;
- in a transport belt dryer, the material is transported by a belt;
- in an air floating dryer, the material is transported by specially designed air nozzles;
- in a festoon dryer long loops are hung on poles which move slowly through a sealed room.

The VOC evaporating from the adhesive layer during drying is captured with part of the exhaust air from dryer. For safety reasons, a maximum solvent concentration is maintained in the exhaust air, calculated using EN 1539. The safe working level maintained is 50 % of the lower explosion limit. A reduction of the solvent concentration of the dryer's air is controlled by the air flowrate. If gas-tight inert gas dryers are used, higher solvent loads are possible. The load depends on the solvents used and the drying temperature.

The exhaust air of the dryers is usually cleaned by solvent recovery. This is carried out by condensation in the pre-drying stage (captured fugitive emissions from the mixing and application units) and by adsorption on activated carbon in the drying stage. Solvents are recaptured by steam desorption and trapping.

There is no waste from the processes of drying and waste gas treatment. Minor amounts of waste water result from the desorption process in the waste gas treatment.

### **Winding**

Before rewinding, the tape has to be cooled down in a cooling unit with cooling rolls. The cooling is done by the use of cooling water.

After cooling, the tape is rewound on large rolls ready for transport to the slitting process.

The solvent proportions remaining in finished double-sided adhesive tapes produced with solvent-based adhesives account for between 0.1 and 2 % based on the amount of solvent used. Solvents remaining in the products are either slowly lost due to diffusion processes or they remain in the adhesive layer functioning as a plasticiser.

At this stage of the production process, waste may result from faulty charges and as slitting rest. The amount of waste normally remains below 10 % of the material input.

There is no waste water.

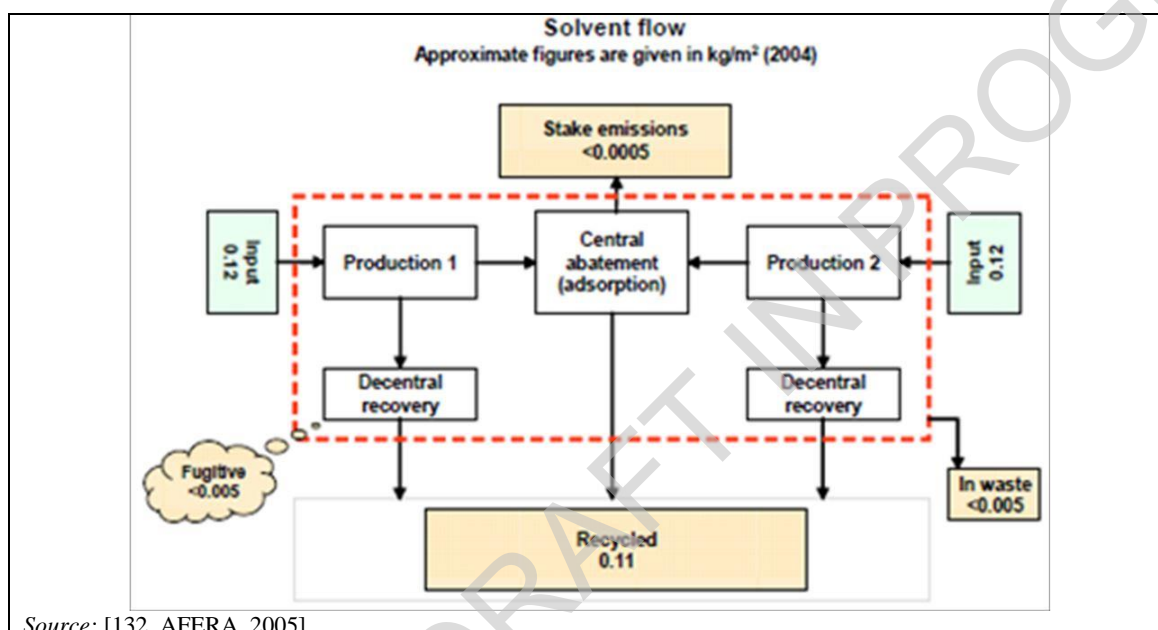
## 7.3 Current consumption and emission levels in adhesive tape manufacturing

[78, TWG, 2005] [132, AFERA, 2005] [155, TWG, 2016]

### 7.3.1 Consumption

#### 7.3.1.1 Consumption of raw materials

The adhesive material is usually produced in house and has a solid content which could vary from < 1 % up to 80 % depending on the product type, the substrate (backing) material and the production process. The adhesive material specific consumption value could vary from 10 g/m<sup>2</sup> to 30 g/m<sup>2</sup> of produced tape and the corresponding specific solvent consumption could vary from 0.05 g/m<sup>2</sup> up to 5 g/m<sup>2</sup>.



**Figure 7.4:** Solvent flow (2004 data)

#### 7.3.1.2 Energy consumption

Data from two reference installations show that the specific energy consumption varies from 0.2 kWh/m<sup>2</sup> up to 1 kWh/m<sup>2</sup>. Of the total energy usage, 60–80 % relates to fossil fuel consumption for steam generation and the rest to electricity which also covers heating, ventilation and air conditioning (HVAC) needs.

A reduction of the energy consumption is gained by:

- the use of heat exchangers in the dryers;
- optimised insulation of the dryers.



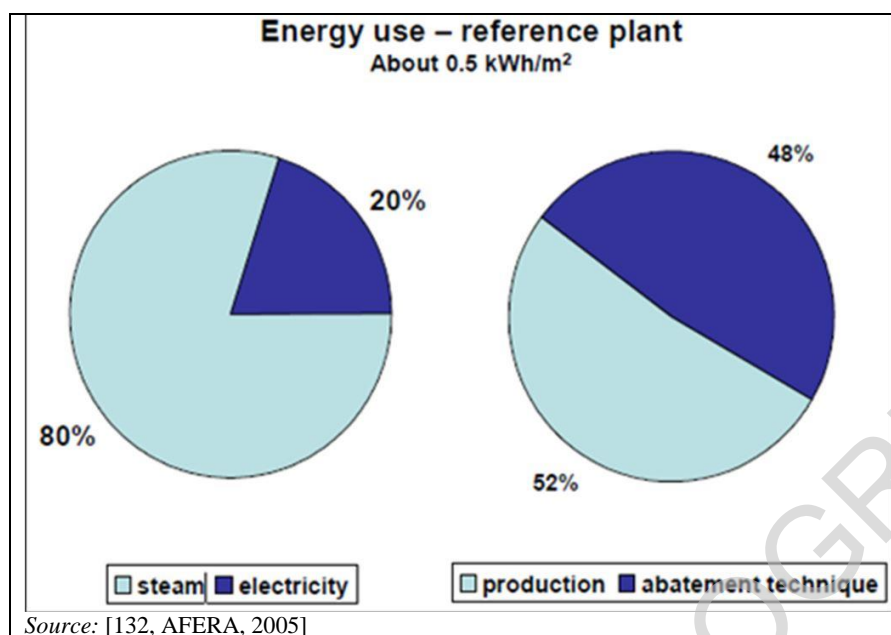


Figure 7.5: Energy consumption (2004 data)

### 7.3.1.3 Generation of waste

Data from one installation show a specific waste generation value of the order of 0.1 kg/m<sup>2</sup> of produced tape.

Reference waste generation data (from 2005) are presented in Figure 7.6

#### General background on industries using adhesives

In the IED, the manufacture of adhesive tapes is grouped with other using industries adhesives. Other relevant industries that are:

- addressed in this document: the production of adhesive tapes, abrasives, the transportation sector (passenger cars, commercial vehicles, rail vehicles, and aircraft), and the wood material and furniture industry
- not addressed in this document: composite foils, mobile homes, the manufacture of shoes and leather goods.

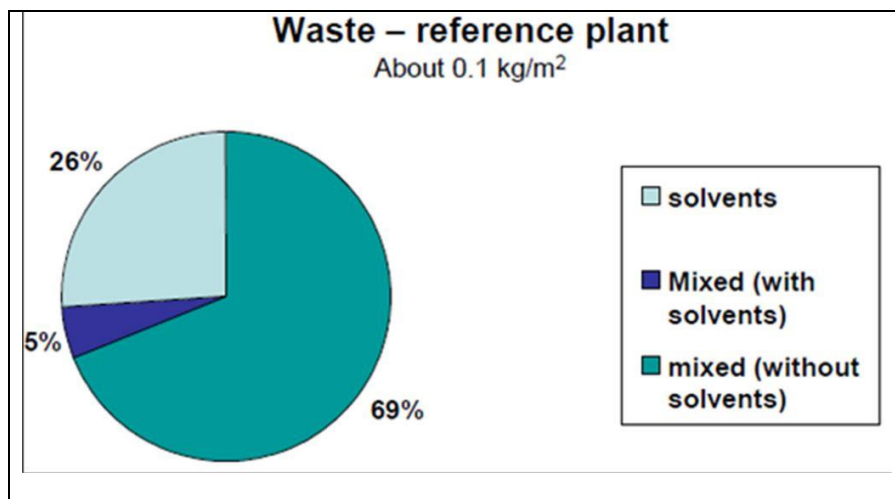
Adhesive tape manufacture cannot be disaggregated from the following data, but it does provide some background. At a EU 25 level in 2000 (according to the RAINS model) NMVOC emissions were 257.6 kt representing 2.4% of total NMVOC emissions. Total activity was 680 kt of adhesives used, and the average emission factor is about 378.8 g NMVOC/kg of adhesives meaning that emissions from this sector are already partly treated\* in EU 25 (the untreated\* emission factor being 780 g/kg). The EGTEI data estimate reductions achievable across all the solvent using industries to be 76 to 98 %. It is not known how representative this is of adhesive tape manufacture. (\*Treated/untreated in this context means not only waste gas treatment but also other measures to reduce VOC emissions).

#### Specific data for the production of adhesive tapes

The following tables and figures show basic consumption data and a mass balance for a modern reference plant producing high quality solvent based adhesive tapes for very specific industrial uses:

Production time	20 shifts a week
Products	About 50 million m <sup>2</sup> /year with about 75 % high coating weight

Table: Conditions of production for a solvent based adhesive tape production plant



**Figure 7.6: Waste generation (2005 data)**

The amount of waste is reduced by:

- process optimisation by risk analysis (the FMEA process: failure mode and effects analysis) avoiding quality problems;
- continuous process control to avoid non-conforming products;
- optimisation of adhesive mixing to avoid excess materials with limited shelf life ;
- an efficient solvent recovery system.

The specific consumption and emission values are significantly dependent on the types of manufactured tapes (type of solvent, substrate, coating weight) and will decrease with:

- a decreasing number of different products during the production period (longer campaigns);
- a lower share of double sided tapes in the production.

Table 7.3 shows the specific consumption figures of the reference plant in comparison with average data from other solvent-based productions.

**Table 7.3: Benchmark comparison for solvent and energy used and waste generated**

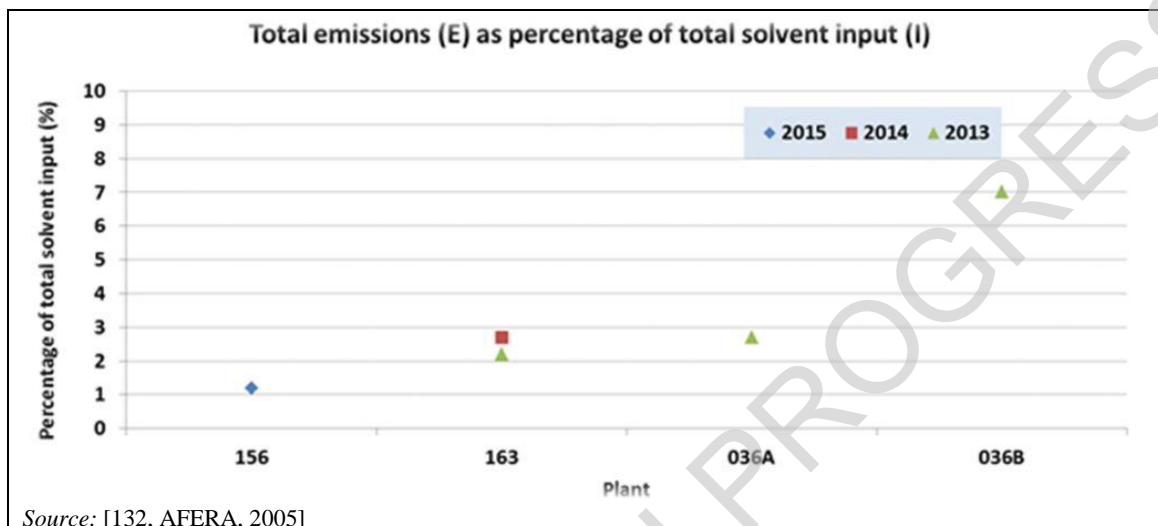
	Solvent used (kg/m <sup>2</sup> )	Energy used (kWh/m <sup>2</sup> )	Waste generated (kg/m <sup>2</sup> )
<b>Average data</b> (Min.–Max.) (normal production)	0.04 (0.02–0.12)	0.5 (0.25–1.1)	0.03 (0.005–0.1)
<b>Reference plant</b> (special production)	0.12	0.5	0.10

NB: This table very clearly expresses the higher specific consumption of specialised production (as in the reference plant) compared with the average level of commodities produced in other solvent-based plants.

## 7.3.2 VOC emissions

### 7.3.2.1 Total and fugitive VOC emissions

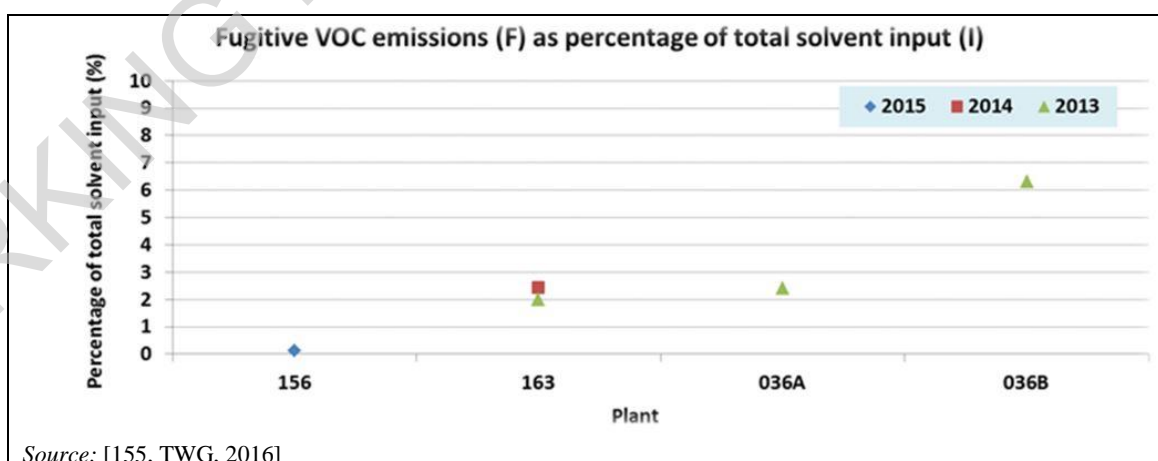
The reported total emissions expressed as a percentage of the total solvent input are presented in Figure 7.7.



**Figure 7.7:** Total VOC emissions values expressed as a percentage of the total solvent input

Data show that all but one total VOC emission values are well below 5 % of the total solvent input. The deviated figure for one installation is mainly attributed to the relatively high percentage of fugitive emissions compared to the corresponding values for the other installations, as can be seen in Figure 7.8.

All plants reported either full encapsulation of coating machines or enclosure of the production hall and full dryer encapsulation with extraction and subsequent treatment using activated carbon adsorption and recovery.



**Figure 7.8:** Fugitive VOC emission values expressed as a percentage of the total solvent input

In Plant 036A, rubber, solvent (hexane) and resins are used for the adhesion while plant 036B uses a hot melt process. In both lines, a release coat is applied by using toluene. Therefore, the differences in the achieved total (and fugitive) emission values between the two lines of the

same installation could be explained on the basis of higher fugitive emissions of the release coat application in comparison to the hexane-based adhesive coating

### 7.3.2.2 VOC emissions to air in waste gases

[155, TWG, 2016]

VOC emissions to air in waste gases were reported from only four out of the nine monitoring points for three adhesive tape manufacturing installations. At eight of the nine waste gas emission streams, the applied abatement technique is activated carbon adsorption and at one RTO is applied. All reported values are lower than 50 mg/Nm<sup>3</sup>.

The VOC balance for the described reference plant is presented in Figure: ——— below.

#### **Figure: VOC balance of the reference plant**

[132, AFERA, 2005]

As can be seen from this VOC balance, the emission limits for such installations are low and emission values of 5 wt % or less can be achieved. Important elements for gaining good emission values are:

- using non-solvent techniques for manufacturing suitable products (currently lower quality ranges of packaging and masking tapes, and double-sided tapes);
- capturing of emissions from solvent storing and adhesive mixing ;
- encapsulation of the whole coating machine and leading all emissions from all fugitive sources to the waste gas treatment; waste gas treatment can be one or a combination of:
  - condensation, after a pre-drying step (see Sections 7.4.4.1, 7.4.3.1 and 17.8.1);
  - absorption with a recovery of > 90 % and emissions of < 1 % (see Sections 7.4.4.2, 17.10.6.3 and 17.12.7.1);
  - oxidation with energy recovery (see Section 17.10.5);
  - additional specific capturing of VOC emissions direct from the coating units (see Section 17.10.2);
- decreasing the number of different products during the production period (longer campaigns) avoiding the need for interim cleaning.

## 7.4 Techniques to consider in the determination of BAT for the manufacturing of adhesive tape

In Chapter 17, techniques are discussed which might also be applicable to the manufacturing of adhesive tape. In Table 7.4, the general techniques relevant for the manufacturing of adhesive tape are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

The EGTEI synopsis sheet for the industrial application of adhesives (see Annex 21.3.1) gives some data on the cost-benefit at a European level of some techniques to reduce VOC emissions. However, the EGTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as cross-media effects or of the technical characteristics of individual installations and products [83, EGTEI, 2005].

**Table 7.4: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### **Conventional solvent-based adhesives**

*Conventional techniques have been deleted if they can no longer be considered BAT.*

*This does not prohibit their use or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumption or emissions.*

**Description:** Solvent based adhesives have to be applied for achieving specific properties, e.g. to meet high stress resistance. There are no solvent free adhesives currently available that show equivalent properties.

**Achieved environmental benefits:** No data submitted.

**Cross-media effects:** No data submitted.

**Operational data:** No data submitted.

**Applicability:** Applicable in new and existing plants and installations.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** Widely used.

**Reference literature:** [14, DFIU and IFARE, 2002]

#### **7.4.1 Material-based techniques [~~Replacement of conventional solvent-based adhesives (substitution)~~]**

It is important to note that these are only options for producing limited types of tapes and for a new or upgraded plant, as these substitutions require a complete change of equipment [78, TWG, 2005].

##### **7.4.1.1 Hot melt adhesives**

###### **Description**

Hot melts do not contain solvents.

###### **Achieved environmental benefits**

Solvent emissions are eliminated.

###### **Cross-media effects**

No data submitted.

###### **Operational data**

No data submitted.

###### **Applicability**

Applicable in new and existing plants and installations. In the manufacturing of adhesive tapes, hot melts are suitable for the lower quality range of packaging and masking tapes as well as for double-sided tapes.

###### **Economics**

No data submitted.

###### **Driving force for implementation**

No data submitted.

###### **Example plants**

No data submitted.

###### **Reference literature**

[14, DFIU and IFARE, 2002]

##### **7.4.1.2 Water-based adhesives**

###### **Description**

Water-based adhesives do not contain organic solvents.

###### **Achieved environmental benefits**

Solvent emissions are eliminated.

###### **Cross-media effects**

More energy is required for drying.

###### **Operational data**

No data submitted.

###### **Applicability**

Applicable in new and existing plants and installations. In the manufacturing of adhesive tapes, water-based adhesives are suitable for the lower quality range of packaging and masking tapes as well as for double-sided tapes.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[14, DFIU and IFARE, 2002]

**7.4.1.3 UV curing adhesives****Description**

UV curing adhesives do not contain solvents.

**Achieved environmental benefits**

Solvent emissions are eliminated.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

Applicable in new and existing plants and installations. In the manufacturing of adhesive tapes, UV curing adhesives are suitable for the lower quality range of transfer and packaging as well as for masking tapes.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[14, DFIU and IFARE, 2002]

**7.4.2 Replacement of conventional solvent-based adhesives manufacturing (substitution)****7.4.2.1 Solvent-free manufacturing of adhesive tape****Description**

A new production process for the manufacturing of technical adhesive tapes was scaled up to a full size production line in one plant in Europe. The new process is based on hot melt

technology which is adopted for the very specific needs of existing solvent-based products for industrial uses. This has been made possible by product modifications, product campaign mergers and intensive product and application support for costumers to ensure acceptance of the new products and their fitness in use.

#### Achieved environmental benefits

In comparison to solvent-based processes, solvent emissions, solvent use and process water use are reduced to zero. The primary energy consumption is reduced to 33 %.

#### Cross-media effects

This technique involves the cross-linking of polymers leading to ozone generation. Ozone emissions are destroyed by an eliminator (catalyst) achieving emission values of 0.05 ppm.

#### Operational data

A range of products can be manufactured with an adhesive application of 30–110 g/m<sup>2</sup>. Integrated automated processes without manual operation gives high materials efficiency. Table 7.5 shows a comparison between a natural rubber process using solvents and a solvent-free natural rubber process for one plant. Actual figures will vary depending on the products manufactured.

**Table 7.5: Comparison between a natural rubber process using solvents and a solvent-free natural rubber process**

Energy	Solvent-based process	Solvent-free process
Steam (t) for regenerating activated carbon (kWh)	25 145	0
corresponding to fuel oil use (t)	14.75 million approx. 1 700	0
Electricity (kWh) corresponding to fuel oil use (t)	6.71 million approx. 1 650	4.5 million approx. 1 100
Process water use (m <sup>3</sup> )	approx. 25 000	0
Total energy use (kWh)	21.46 million	4.5 million
Total equivalent fuel oil use (t)	approx. 3 350	approx. 1 100
NB: The energy consumption is related to a production output of 100 million m <sup>2</sup> .		

#### Applicability

Not all existing products can be produced by this new installation. It is necessary to redefine the product specification together with the client if a change to this technique is envisaged.

The application of this new technique requires fundamental changes in all parts of an installation. It is only an option for new installations or for one undergoing extensive upgrading.

Gaining the efficiency advantages described requires a homogenous production portfolio.

#### Economics

The capital investment for the new installation was EUR 13.4 million. Savings in energy are about 66 %. There is no expenditure on waste gas treatment, monitoring, and other compliance with emission controls, etc., as these are not necessary.

Economical operation of this technology can only be achieved for large scale installations.

#### Driving force for implementation

~~Solvent Emissions Directive 1999/13/EC.~~ Adoption of new technology to respond to current and new market requirements.

#### Example plants

Tesa AG, Hamburg, Germany.



**Reference literature**

[38, TWG, 2004, 78, TWG, 2005] [132, AFERA, 2005]

**7.4.3 Drying****7.4.3.1 Inert gas convection drying**

For a general description, see Section 17.8.1. This technique is commonly applied as a pre-drying step in adhesive tape manufacturing.

[14, DFIU and IFARE, 2002]

**7.4.3.2 Infrared radiation curing**

For a general description, see Section 17.8.3.1. This dryer is commonly used in adhesive tape manufacturing and is suitable for dispersions and also for solvent-based adhesives if explosion protection is needed.

[13, DFIU and IFARE, 2002] [14, DFIU and IFARE, 2002]

**7.4.3.3 Ultraviolet (UV) curing**

For a general description, see Section 17.8.5.2. UV curing is increasingly applied in the production of adhesive tapes. It is used especially for newer acrylate hot melts. It is also used for radiation curing adhesives, where the final reticulation and the adjustment of the technically required cohesiveness and adhesive strength are initiated by UV radiation.

[13, DFIU and IFARE, 2002] [14, DFIU and IFARE, 2002]

**7.4.3.4 Electron beam curing (EB)**

For a general description, see Section 17.8.5.3. EB curing is increasingly applied in the production of adhesive tapes, however, less than UV curing (see Section 7.4.3.3) due to higher investment costs. Also, compared to UV curing, changes in substrate properties are possible.

[13, DFIU and IFARE, 2002] [14, DFIU and IFARE, 2002]

**7.4.4 Waste gas treatment****7.4.4.1 Condensation (refrigeration)**

For a general description, see Section 17.10.6.1. Used solvents can be recovered by applying condensation in a recuperative heat exchanging device and cooling (5 °C to -30 °C) by a refrigerant compressor. In adhesive tape manufacturing, condensation is applied after a pre-drying step using an inert gas nozzle dryer (see Sections 7.4.3.1 and 17.8.1) and before the main drying process. This is followed by an adsorption step for the waste gas.

[14, DFIU and IFARE, 2002]

**7.4.4.2 Activated carbon adsorption and recovery on site**

For a general description, see Sections 17.10.6.3 and 17.12.7.1. The waste gas loaded with solvents flows through adsorbers that are generally constructed as several parallel connected tanks. The tanks are filled with activated carbon. If one adsorber is saturated, the waste gas is routed to the adjacent adsorber. For regeneration, the adsorbed solvents are first desorbed due to a rise in temperature initiated by steam supply. The water-solvent mixture being formed is then

condensed and parted by phase separation. Emission concentrations of 70–90 mg/m<sup>3</sup> are achieved in the cleaned gas.  
[14, DFIU and IFARE, 2002]

#### **7.4.4.3 Regenerative thermal oxidation (RGO)**

For a general description, see Section 17.10.5.

WORKING DRAFT IN PROGRESS

## 8 COATING OF TEXTILES, FOILS AND PAPER

*TWG please provide more information*

### 8.1 General information

[163, Kovacevic et al., 2010] [164, Singha, 2012] [165, EURATEX, 2016]

This chapter covers the sector of coating of various substrates (textile, foils, paper) with different end uses and similar application techniques.

Coating and laminating are increasingly important techniques for adding value to technical textiles. Coating and lamination enhance and extend the range of functional performance properties of textiles and the use of these techniques is growing rapidly as the applications for technical textiles become more diverse.

Textile and apparel manufacturing is an essential pillar of the local economy across the EU regions. One federation alone represents some 174 000 companies with a turnover of EUR 162 billion, employing 1.66 million workers. The EU is the second world exporter of textiles and clothing with extra-EU exports reaching 28 % in 2014.

### 8.2 Applied processes and techniques

#### 8.2.1 Polyurethane (PU) coating

[163, Kovacevic et al., 2010] [164, Singha, 2012]

Coating is a process in which a polymeric layer is applied directly to one or both surfaces of the fabric. The polymer coating must adhere to the textile and a blade or similar device controls the thickness of the viscous polymer. The coated fabric is heated and the polymer is cured (polymerised). Where a thick coating is required, this may be built up by applying successive coating layers, layer on layer.

The selection of polymers is very important to obtain the desirable properties of the finished product, and the coating composition is determined according to the application of the finished product.

The coating consists of the basic polymer and additives. In the selection of the basic polymer, the properties are as follows: thermoplasticity, mechanical properties of polymers, possibility of film formation, stiffness, good adhesion, abrasion resistance, heat, water and air conductivity, resistance to solvents and hydrolysis, resistance to UV radiation, melting point, etc.

The basic polymer is mostly polyurethane which may be strong and rigid or soft and elastic. Polyurethanes belong to the group of very durable plastic materials. The main property of polyurethane is its wide-ranging application. It can be used to coat textiles, leather, in solution, dispersion, with a low solvent content or without it, as granules or powder. Softness or hardness can be obtained by varying polymer structures.

Polyurethane has good washing and cleaning resistance, good adhesion to the fabric, good durability at low temperatures, good viscosity and abrasion resistance, and it is possible to use it without softeners. At the same time it has a pleasant and soft touch, a low specific mass, and resistance to oils and fats. Polyurethane can be used to coat textile materials in more ways:

- as a two-component polyurethane with isocyanate cross-linking;
- as one-component aromatic or aliphatic polyurethanes with chemical reactions;
- as a one-component product that enables dispersion in water and is environmentally friendly;
- as a solid product with possible coating of greater quantities in each coating passage.

### 8.2.1.1 Coating methods

[164, Singha, 2012] [166, FEDUSTRIA, 2016] [167, FEDUSTRIA, 2016] [168, UK TWG, 2016]

There are several processes for the application of coating to the textile material depending upon the requirement of end product. The most frequently used are the following:

- **Direct coating:** The fabric is stretched flat to form a uniform surface and is transported under a stationary doctor blade. The direct coating process of polyurethane involves the application of multiple coating layers on a textile substrate. Every coating step is followed by a passage through a drying unit to remove the solvent (i.e. DMF).
- **Foamed and crushed foam coating:** This can be used to apply polymer to woven fabrics and knitted fabrics and also to fabric produced from spun yarns or fabrics of a general open construction which cannot generally be directly coated.
- **Transfer coating:** The principle of transfer coating is first to spread the polymer onto release paper to form a film and then to laminate this film to the fabric. Multiple coating layers are applied on release paper and transferred to a textile substrate by means of a PU adhesive layer. Every coating step is followed by a passage through a coater dryer to remove the solvent (DMF). After drying of the adhesive layer, the paper is released from the coating.
- **Hot melt extrusion coating:** This method is used for thermoplastic polymers such as polyurethane, polyolefins and PVC, which are applied by feeding granules of the material into the nip between moving heated rollers.
- **Calender coating:** Calenders are primarily used to produce unsupported films of PVC and rubbers from compounded polymer 'dough'.
- **Rotary screen coating:** Application of a compound to a fabric by forcing it through a cylindrical screen, it is used mainly for textile printing.

### 8.3 Current consumption and emission levels in PU and PVC coating

Data were submitted for 10 plants, 8 of which are textile coating plants (woven and non-woven, knitwear), one a paper and foil coating plant and one a paper, plastic and other substrates coating plant.

**Table 8.1: List of plants that submitted data for the coating of textile, foils and paper**

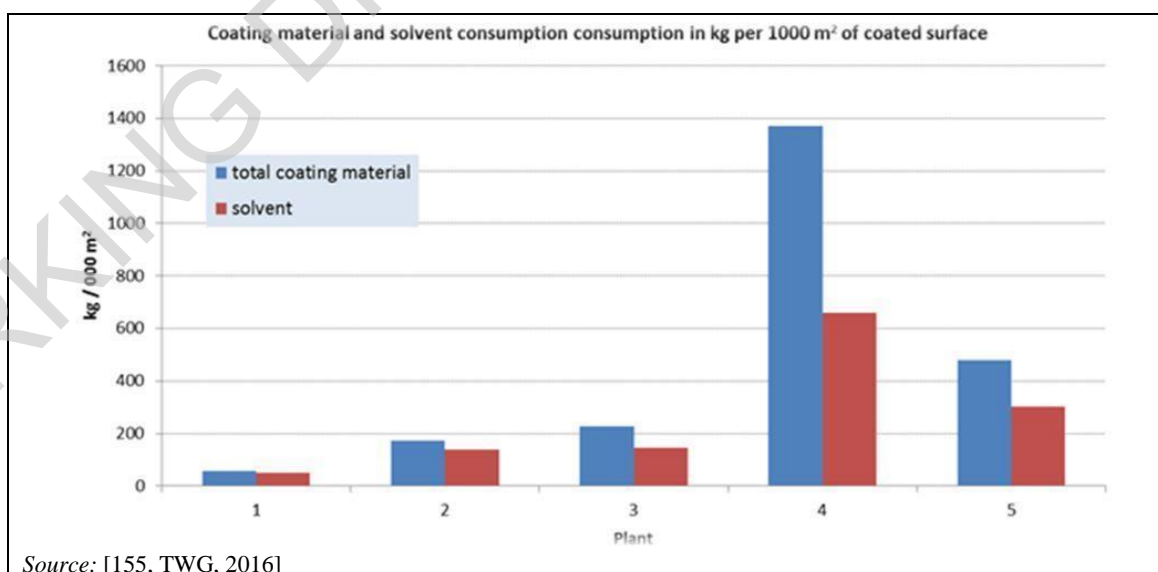
Plant number	Substrate	Coating method
135	Textile non-woven knitted	Transfer coating using transfer paper
166	Knitwear	Transfer coating of knitwear with solvent-based PU
134	Woven textile polyester	PVC direct coating followed by varnish, no PU coating
139	Paper, plastic and other	Direct
137	Foil and paper laminates, metallised paper and pure paper	Indirect
140	Textile woven and non-woven	Indirect - Coating line + lamination line
171	Woven textile	4 direct coating lines + 2 calenders with PU
151	Woven textile	Direct
136	Textile	Both direct and transfer coating
138	Textile	PU line and PVC line

*Source: 155, TWG, 2016*

#### 8.3.1 Consumption

##### 8.3.1.1 Coating material and solvent consumption

For the textile coating plants, the total material (including coating adhesive and cleaning materials) and solvent consumption are presented in Figure 8.1.



**Figure 8.1: Reported values of total material consumption (including coating adhesive and cleaning materials) and solvent (material consumption per 1000 m<sup>2</sup> of coated surface)**

For paper coating, the coating material and solvent consumption is of the order of 1–3 kg/1000 m<sup>2</sup>.

### 8.3.1.1.1 Dimethylformamide (DMF) consumption

The reported figures for DMF use show that DMF represents a percentage share of solvent input that varies from 15 % up to 98 % depending on the process, the materials and the end product specifications.

### 8.3.1.2 Energy consumption

The reported figures for specific energy consumption for textile coating vary from 1 kWh/m<sup>2</sup> up to 25 kWh/m<sup>2</sup> depending on the process and the substrate. For paper coating, a specific energy consumption value of the order of 0.1 kWh/m<sup>2</sup> was reported.

## 8.3.2 Emissions

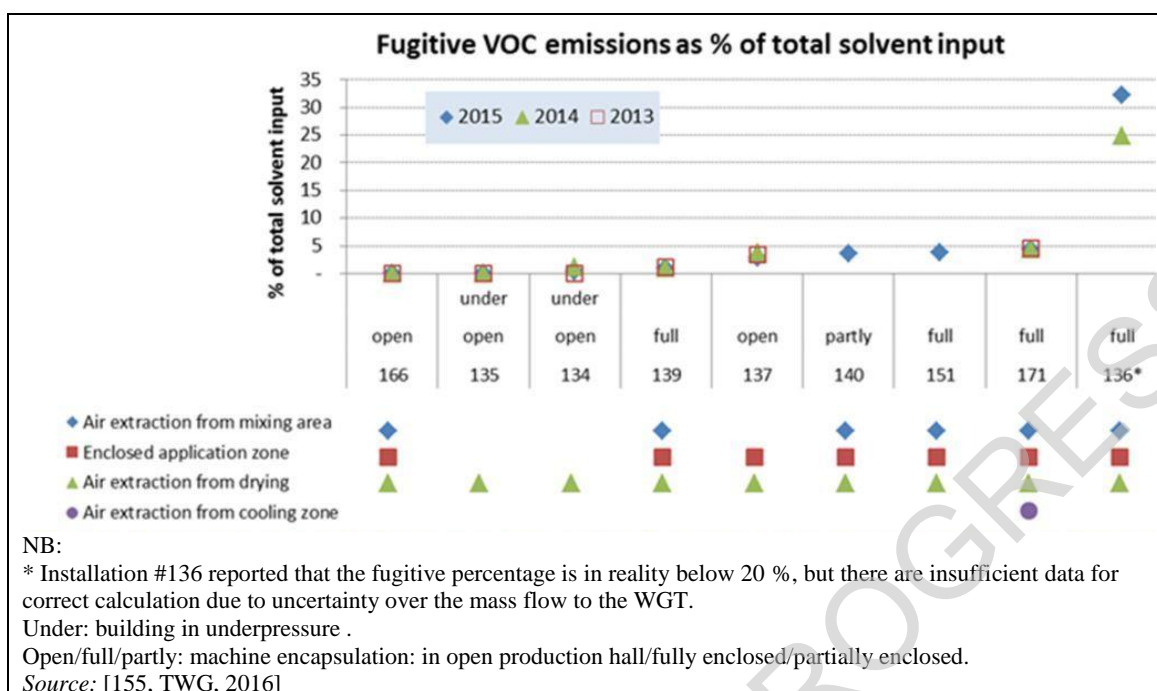
[155, TWG, 2016]

### 8.3.2.1 Fugitive and total VOC emissions to air

In general, coating processes are well enclosed with air extraction and subsequent treatment via adsorption and/or regenerative thermal oxidation. As a result, the fugitive emissions are kept below 5 % of the total solvent input in all but one case (see Figure 8.2). The high value for only one installation is mainly related to the uncertainty on the calculation of the mass flow to the thermal treatment.

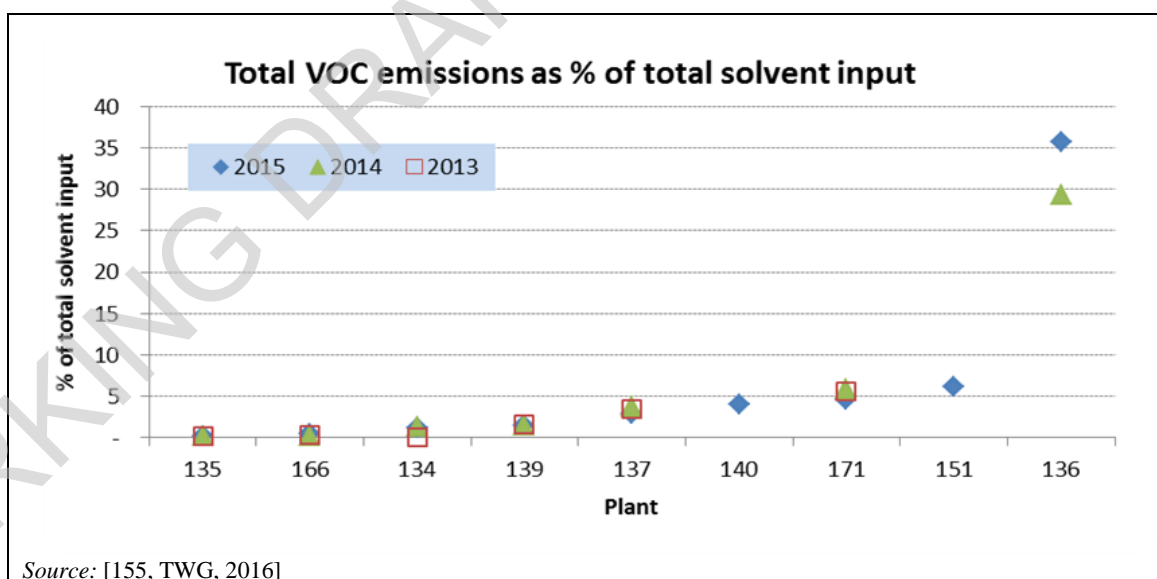
The main reported techniques for the limitation of fugitive VOC emissions are:

- safe storage of hazardous substances and measures to prevent unplanned releases;
- handling and use of hazardous materials;
- air extraction from drying processes and subsequent treatment;
- air extraction from the cooling zone with treatment;
- air extraction of tank breathing from mass storage tanks, benzene tanks and distillation plant; extracted air is conducted to the waste gas treatment;
- air extraction from mixing tanks and mixing area in general, and container for distillation residue is conducted to the waste gas treatment;
- air extraction from container of cleaning materials (clothes etc.) and subsequent treatment;
- enclosed application zones with air extraction;
- maintenance of building underpressure and air extraction and treatment;
- use of water-based coatings; *TWG please provide more information*
- use of alkaline-based washing machines for both rolls and parts cleaning.



**Figure 8.2: Reported values of fugitive VOC emissions as a percentage of the total solvent input for the period 2013–2015**

As a result of the proper enclosure of the process, the air extraction from the solvent-related processes and subsequent treatment, total VOC emissions are only slightly higher than fugitive ones (see notes of Figure 8.2). With only one exception, all reported percentage values are below 6 %.



**Figure 8.3: Reported values of total VOC emissions as percentage of the total solvent input for the period 2013–2015**

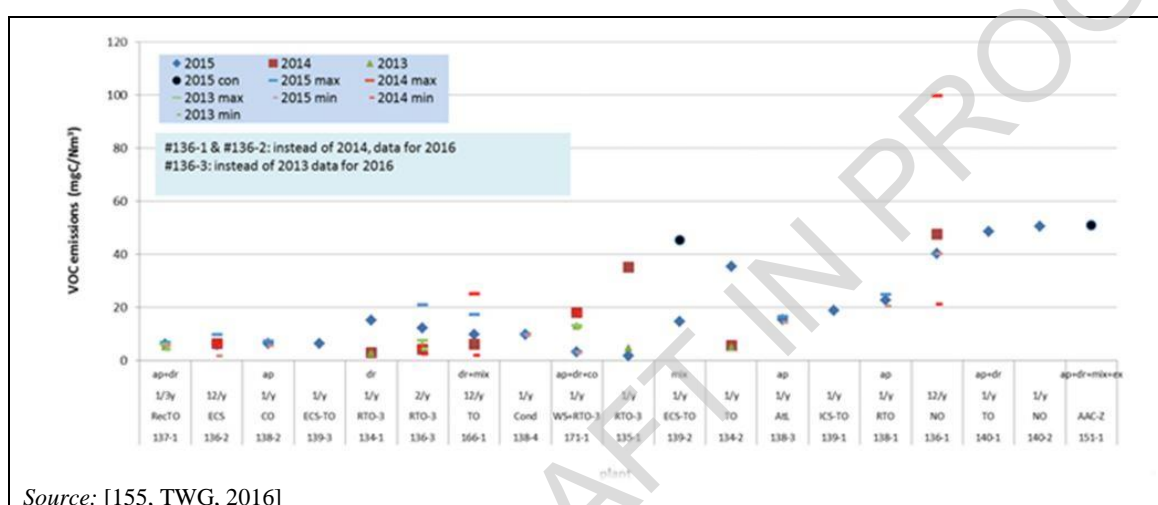
### 8.3.2.2 VOC emissions to air in waste gases

The reported values of VOC emissions to air in waste gases expressed in mg C/Nm<sup>3</sup> are presented in Figure 8.4. The abbreviations used in this figure are explained in Table 8.2. Only

two values for continuous monitoring of VOC emissions were reported. For periodic monitoring, the monitoring frequency varies from once a month up to once every three years.

**Table 8.2: Explanation of abbreviations used**

	Periodicity of monitoring		Abatement technique
1/y	Yearly	ECS	External concentration of solvents
2/y	Every 6 months	RTO	Regenerative thermal oxidation
12/y	Monthly	TO	Thermal oxidation
	Processes	WS	Wet scrubber
ap	Application	AtL	Absorption to liquid
dr	Drying	ICS	Internal concentration of solvents
mix	Mixing process and area extraction	AAC-Z	Adsorption to activated carbon or zeolite
ex	Room air extraction		
co	Extraction from the cooling area		



Source: [155, TWG, 2016]

**Figure 8.4: Reported values of VOC emissions in waste gases expressed as total organic carbon (TOC) in mg C/Nm<sup>3</sup> for the period 2013–2015**

In general, average values are below 50 mg C/Nm<sup>3</sup>.

The basic statistical parameters of the reported data for periodic monitoring of VOC emissions to air the reference period 2013–2015 are presented in Table 8.3.

**Table 8.3: Statistical parameters of reported values for periodic monitoring of VOC emissions to air from textile, paper and foil coating plants for the period 2013–2015**

Parameter	Year	2015	2014	2013
No of measurements		18	8	6
Average		17.9	15.6	5.94
Minimum		1.7	2.86	2.65
25 <sup>th</sup> percentile		6.27	5.11	4.71
Median		13.3	6.17	4.9
75 <sup>th</sup> percentile		21.7	22.2	5.47
Maximum		50.5	47.5	12.9

Source: [155, TWG, 2016]



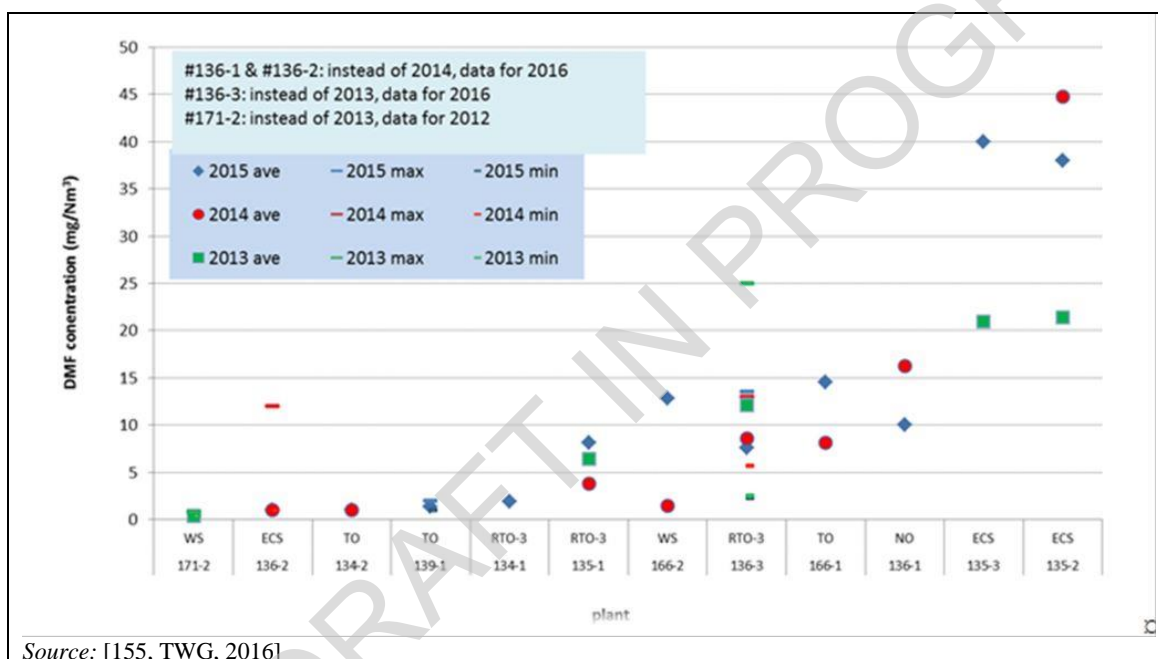
### 8.3.2.3 DMF emissions to air in waste gases

[155, TWG 2016]

The reported values for DMF emissions are presented in Figure 8.5.

From the analysis of submitted data and the contextual information, the following aspects may be considered:

- high values of DMF emissions are measured at installations in Belgium which, since 2015, are applying a new monitoring standard prescribed by the national competent authority;
- different monitoring standards and monitoring frequencies apply in various MS.



Source: [155, TWG, 2016]

**Figure 8.5: Reported values of DMF emissions to air in waste gases (mg/Nm<sup>3</sup>) for the period 2013–2015**

The reported DMF emission values and contextual information on DMF monitoring are presented in Table 8.4.

Table 8.4: Reported DMF emission values and contextual information on DMF monitoring

Emission point number	Abatement technique	Monitoring method	Monitoring frequency	Concentration (mg/Nm <sup>3</sup> ) - Periodic monitoring								
				2015			2014			2013		
				Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.
171-2	WS	065:2010 r0	1/y	ND	ND	ND	ND	ND	ND	0.4	0.8	0.4
136-2	ECS	LUC/IV /010	12/y	1	1	1	1	12	1	ND	ND	ND
134-2	TO	NI	1/y	1			1	ND	ND	ND	ND	ND
139-1	TO	TGN M22	1/y	1.4	2	1	ND	ND	ND	ND	ND	ND
134-1	RTO-3	NI	1/y	1.93	ND	ND	ND	ND	ND	ND	ND	ND
135-1	RTO-3	NI	1/y	8.18	ND	ND	3.77	ND	ND	6.46	ND	ND
166-2	WS	NI	NI	12.82	ND	ND	1.5	ND	ND	ND	ND	ND
136-3	RTO-3	LUC/IV /010	12/y	7.63	13.6	2.28	8.61	13	5.73	12.1	25	2.5
166-1	TO	NI	12/y	14.58	ND	ND	8.13	ND	ND	ND	ND	ND
136-1	NO	LUC/IV /010	12/y	10	ND	ND	16.2	ND	ND	ND	ND	ND
135-3	ECS	NI	NI	40	ND	ND	0	ND	ND	20.9	ND	ND
135-2	ECS	NI	1/y	38	ND	ND	44.7	ND	ND	21.4	ND	ND

NB:  
 NI = No information (contextual)  
 ND = No data (numeric)  
 Source: [155, TWG, 2016]

## 8.4 Techniques to consider in the determination of BAT for the coating of textiles, foil and paper

*TWG please provide more information on sector-specific BAT candidates  
Only short descriptions of direct and transfer coating were provided.*

In Chapter 17, techniques are discussed which might also be applicable to coating of textiles, foils and paper. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to coating of textiles, foils and paper. In Table 8.5, the general techniques relevant for textile, foils and paper coating that are described in Chapter 0 and/or Section 17.7 are shown.

The EGTEI synopsis sheet for other coating sectors (see Annex 21.3.1) gives some data on the costs and benefits of some techniques to reduce VOC emissions at a European level. However, the EGTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as cross-media effects, or of the technical characteristics of individual installations.

**Table 8.5: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

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## 9 MANUFACTURE OF WINDING WIRE

[82, EGTEI 2005] [150, COM 2009] [173, EWWG, 2017] [155, TWG, 2016]  
 [12, UBA Germany, 2002] [54, BMLFUW Austria, 2003] [28, EWWG, 2004]  
 [38, TWG, 2004] [78, TWG, 2005];

### 9.1 General information on the winding wire industry

The manufacturing of winding wires involves a unique type of surface treatment using solvents; basically involving the application of electrical insulation layers (enamels) onto the surface of a copper wire, although in some cases the conductor material may be a different metal like aluminium or brass. These insulation layers are applied for a variety of functional purposes, among which is a high and prolonged dielectric strength throughout the whole lifetime of the wire. The surface also needs a well-defined lubricant covering to ensure a good coiling performance and a smooth laying of the wire.

It should be noted that all information and emission values in all specific winding wire sections are given for copper winding wires, because of their predominant market share. In the case of aluminium wire manufacturing, all specific emission limits and achievable emission figures need to be adapted according to the smaller specific weight of the product using a conversion factor according to the ratio of the specific weights of copper and aluminium.

~~The manufacturing of winding wires involves a unique type of surface treatment using solvents; basically involving the application of an electrical insulation layer (enamel) onto the surface of a copper wire, although in some cases the substrate may be aluminium wire. This insulation layer is applied for functional purposes rather than just for decoration or protection, with the enamel layer needing to provide high and prolonged dielectric strength throughout the whole lifetime of the wire on a coil core. The surface also needs a well defined lubricant layer covering to ensure good coiling performance and a smooth laying of the wire.~~

~~It should be noted that all information and emission values in all specific winding wire sections are given for copper winding wires, because of their predominant market share. In the case of aluminium wire manufacturing, all specific emission limits and achievable emission figures need to be adapted according to the smaller specific weight of the product using a conversion factor of 3.29 according to the ratio of the specific weights of copper and aluminium (8.9 and 2.7 g/cm<sup>3</sup> respectively).~~

Table 9.1 gives figures for the production of enamelled wires in Europe over the period 1970 to 2010 and the correlated use of organic solvents.

**Table 9.1: European production figures for enamelled wires and the correlated consumption of organic solvents from 1970 to 2010**

Year	Production (t)	Consumption of organic solvents (t)	Specific consumption of organic solvents (t/t)
1970	150 000	11 250	0.075
1990	286 000	20 020	0.070
2000	390 000	25 350	0.065
2006	420 000	21 000	0,050
2010	350 000	17 500	≤ 0.050

*Source: 173, EWWG, 2017*

According to ESIG<sup>24</sup>, the total consumption of hydrocarbon solvents in Europe was about 2.3 million t/yr for the EU-27 in 2009. From Table 9.1, it can be estimated that the share of the winding wire industry is about 0.8 % of this.

~~According to ESIG, the total consumption of solvents in Europe is about 4.5 million t/yr. From it can be seen that the share of the winding wire industry is 0.6 % of this.~~

The European winding wire industry comprises about 420 installations and nearly 3 000 workers. A typical installation falling under IED Annex I has 50 to 250 employees; with most being family-owned.

As electric and electronic products are manufactured and sold worldwide, the winding wires used in these products are manufactured according to international standards. Insulating materials are classified in the technical terms of delivery in the EN 60317 standard series. As a consequence, the wires are manufactured to the customer's specifications for their approved type of product, and the manufacturer is not free to select the type of coating. Winding wires can be produced in many hundreds of dimensions, but they are generally grouped as follows:

**Table 9.2: Groupings of winding wire types**

Wire type	Above (mm)	Up to and including (mm)
Ultrafine wires	-	0.040
Fine wires	0.040	0.10
Medium wires	0.10	1.0
Thick wires	1.0	6.0
<i>Source: 173, EWWG, 2017</i>		

Additionally there are rectangular shaped winding wires from small size to big sizes of about 80 mm<sup>2</sup>.

### 9.1.1 Product characteristics and end use applications

The enamelled wire is useful for its very thin, high specification insulating film, which allows close packed and energy efficient winding wires to be produced, which can operate at high temperatures. The insulation consists of one or more layer(s) of enamel or tape(s) or a combination of both. The choice of the insulation material results in typical electrical properties like breakdown voltage, loss factor, corona resistance, partial discharge behaviour. Thermal stability of the wire coating materials is characterised by a temperature index. Other specific requirements for insulating coating systems for wires are mechanical strength, chemical resistance, and overload current stability. Contemporary electrical insulating systems already meet these requirements within thin layers (see CENELEC Standard EN 60317 series for details). Electrical properties especially make winding wires a unique product not comparable with other products under the scope of this document.

The main use of winding wire is in magnetic wires in windings and coils. These are used in a wide range of applications such as miniature coils for medical devices, entertainment electronics (microphones, audio and video heads, etc.), ultrafine wires in watches, and as windings for electrical motors, relays and power transformers. In electrical equipment, the winding wires operate under voltage and conduct currents. The electrical insulation directly affects the functionality and also the safety of the equipment. The electrical properties of the insulation material and the application systems is an essential point to consider when discussing BAT.

<sup>24</sup> ESIG - European Solvents Industry Group, Solvent VOC inventories for EU (2013).

During the last few years, many attempts have been made to introduce alternative insulating materials and application systems in order to reduce the use of solvents. Many of these have failed because of insufficient insulation properties, although there are some semi-successful niche products, e.g. using creosol-free enamels, electrophoresis, powder coating on strips, UV curing coating, and extrusion coating. However, these have not yet been taken up as general standards.

WORKING DRAFT IN PROGRESS

## 9.2 Applied processes and techniques in winding wire manufacturing

[82, EGTEI 2005] [150,, COM 2009] [173, EWWG, 2017] [155, TWG, 2016]

[12, UBA Germany, 2002] [54, BMLFUW Austria, 2003] [28, EWWG, 2004] [38, TWG, 2004] [38, TWG, 2004]

This is a small industry and in Europe there are only about four ~~three~~ producers of the machines used to make winding wires. The same technology will therefore be found in nearly all installations. The manufacturing process for enamelled wires is generally linear: after the production of the bare copper wire by drawing or rolling, thermal cleaning or annealing of the bare wire is carried out, both of which are solvent-free processes. Enamel coating, drying and curing of the resin and then lubricant application are the following steps. Solvent use only occurs during enamel coating, and, depending on the specific process, lubricant application; drying and curing also gives rise to solvent emissions.

### 9.2.1 Typical manufacturing process for enamelled wires

A typical manufacturing process for enamelled wires is shown in Figure 9.1.

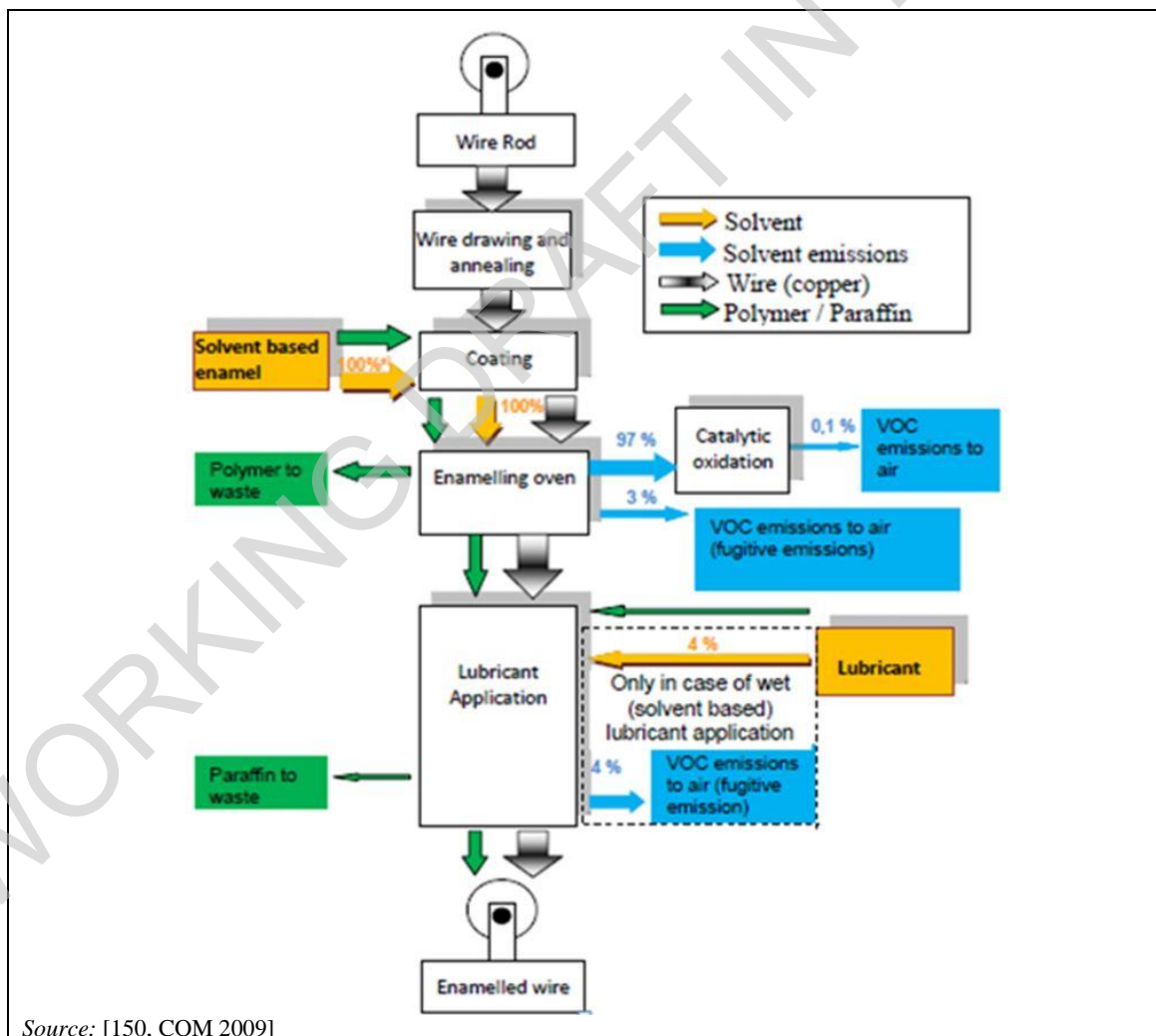


Figure 9.1: Typical manufacturing process and flow chart for winding wire coating



**Figure: Typical manufacturing process for enamelled wires [28, EWWG, 2004]**

### Rolling and drawing

These are deformation processes. Rolling is a continuous or stepwise forming process under compressive conditions. The material can be rolled at ambient or elevated temperatures. Wires for enamelled and other insulated winding wires are preferably manufactured by a drawing process. The wire is drawn through dies which reduce its size and extend its length. Fine wires require several drawing stages to reach the desired dimension. The drawing process applies tractive and pressure stress to the drawn material.

### Annealing

The wire drawing process is followed by annealing where the wire passes through heated tubes (containing an inert atmosphere to prevent oxidation) and leading to recrystallisation and softening of the wire.

### Enamel coating

The next process step is enamel application followed by the drying and curing of the enamel film. The coating is normally applied to the moving wire by the following methods:

- Passing the wire continuously through a bath of enamel (with a solvent concentration of 50–80 %, depending on the product) and metering the amount by an accurately sized die. Each layer applied is typically 1–10  $\mu\text{m}$  thick, depending on the wire diameter, to allow the solvents to evaporate as the wire moves through the enamelling oven. Typically 5 to 10 layers are applied onto the surface of the winding wire. Dies are cleaned with solvent before reuse.
- Dosed coating supply and felt application: the wire is pulled through a felt impregnated with a solvent-based coating. This technology is typically used for fine winding wires due to the gentle application. The felt has to be treated as waste afterwards.

### Drying and curing

The coated wire then passes into the enamelling chamber, which consists of a heated chamber (horizontally or vertically arranged) where the solvent is evaporated before moving into a higher temperature zone (400–700 °C) where the film is cured. The wire may then go back into the coating circuit for an additional layer of coating. In this continuous coating process, up to 30 applications of enamel may be applied until the desired layer thickness is obtained.

Recirculated airflow ovens are in use for contemporary wire coating processes. The direction of the recirculating airflow can be with or against the direction of the moving wire. Recirculating the airflow has the advantage that the vented volumes can be decreased. The solvent evaporation process leads to evaporation of the solvent and the air/solvent mix is usually treated in a catalytic oxidiser which ensures that residual solvent concentrations are below legal threshold limits (typically 20–30 mg organic C/Nm<sup>3</sup>). The process heat from the thermal oxidiser can be used in the drying process for the heat up of the circulating airflow (loop).

In gas heated machines, solvent-laden air is passed directly into a gas burner, where the design of the burner allows intimate mixing of the secondary air and oxidation occurs. To ensure that the solvent concentration does not rise beyond the lower explosive limit, it is important that excess air is supplied.

Using electrical heating, the solvent-laden air is passed over heating elements to reach a temperature in excess of 500 °C. This is generally sufficient to achieve complete support the catalytic oxidation. In all cases, electrically heated machines use precious metal catalysts. The efficiency of oxidation is sufficient to ensure that emission control limits for VOC emissions are always achieved. After thermal or catalytic oxidation of the solvents, the air stream is recirculated to provide complete or partial heating of the enamelling chamber. Exhaust gas velocities may be lower than other industries to ensure a maximum energy efficiency balance

from the use of recirculated air. It is important that any oxidation takes place where the air stream is recirculated. Oxidation in the stack will produce only hotter exhaust air.

~~Contemporary ovens in use for very fine enamelled wires work with radiation or a combined radiation and circulating airflow.~~

Contemporary ovens in use for very fine enamelled wires work with heat transfer by radiation or a combined radiation and circulating air flow/convection.

The enamelling chamber is typically maintained under negative pressure to allow capture of any fugitive emissions from the enamel supply system and to contain any degradation products or products of combustion from entering the workplace air. ~~An enclosure around the enamel applicator further reduces fugitive emissions from liquid enamel.~~

### **Lubricant application**

Depending on the final product requirements, the enamelled wire may be lubricated before being wound onto a reel. Several lubricants contain different volatile organic solvents.

The lubricant layer is necessary for the coil winding operation. Too little or too much lubricant makes the winding wire sticky and prevents close coiling. The lubricant film is nearly mono-molecular with about 30–60 mg/m<sup>2</sup> of lubricant applied for medium or thick wires and 5–10 mg/m<sup>2</sup> of lubricant applied for fine wires with a diameter below 0.10 mm.

The solvent-based lubricant cannot be dried in the enamelling oven as the wax would burn off at such high temperatures. Therefore drying takes place at room temperature in a non-encapsulated area (required drying distance ~ 10 m). Extraction and subsequent incineration of these large quantities of air with low VOC concentrations (50–100 ppm) and temperature would be very inefficient and energy-consuming. The solvent from the lubricant accounts for about 60 % of the fugitive emissions from the process as a whole.

Typically paraffin is applied from an organic solvent with a solvent content from 98 % to 99.9 %. Lubricants, as concentrated emulsions, with a solvent content of between 50 % and 95 %, water-based emulsions or even solvent-free hot melts are also used in this industry, though with limited success. With respect to the use of solvent-free alternatives, customer quality requirements with respect to thickness and evenness of the lubricant film have to be respected. The lubricant is generally specified by customers. Generally, it can be stated that high quality requirements and thin wires are less appropriate for solvent-free lubricants. Wherever possible, customers should be encouraged to use products such as self-lubricating enamels or solid wax.

An alternative to solvent application may be the application of a molten lubricant to the wire surface by a lubricant wetted felt or by feeding the finished enamelled wire with a lubricant filament that melts due to the residual heat of the wire. The latter technique applies the lubricant by looping the filament two or three times around the enamelled wire and moving it in the same direction as the wire, although at a lower velocity. Both techniques are not yet suitable for applying lubricants to fine wires with diameters of less than 0.1 mm.

## 9.3 Current consumption and emission levels in winding wire manufacturing

### 9.3.1 Consumption

[155, TWG, 2016]

#### 3.3.1 Mass balances

[12, UBA Germany, 2002] [54, BMLFUW Austria, 2003]

The range of diameters of the wires produced (between 0.01 - 6.0 mm) results in a large variation between production quantity (tonnes wire) and product surface coated (m<sup>2</sup>). As a consequence, the technologies and varnishes applied for fine wires are different from those for larger diameter wires.

Reported data on raw material consumption show an average solvent consumption between 70 kg and 80 kg per tonne of copper.

Mass balances of two different types of existing installations in Germany are shown below; the data in Table and Table are given as specific values related to 1000 kg final product. These data are very similar to the consumption and emission levels of two production plants in Austria.

The first plant from which the consumption and emission data are shown in Table can be described as follows:

- installation M: produces medium wires, predominantly with a diameter of 0.6 mm, three shift operations over 320 to 340 days per year, typical capacity 90 t wire per line/per year.

Input		Output	
<b>Raw materials</b>			
Cu-wire (8 mm)	1070 kg	Product (Cu-wire 0.6 mm)	970 kg
		Wire residues (bare and coated)	100 kg
<b>Varnishes and solvents</b>			
Polymer in varnish	38 kg	Varnish on product	30 kg
		Polymer losses	8 kg
Solvents	71.5 kg	Solvents in waste	4.7 kg
		Catalytic oxidation of VOCs <sup>(1)</sup>	58.6 kg
		Emitted VOCs	8.2 kg
		NO <sub>x</sub>	
		CO	(2)
		CO <sub>2</sub>	
<b>Process materials</b>			
Water	~1000 kg	Water	~1000 kg
Wax	0.1 kg	Wax	0.1 kg
Drawing compound	0.3 kg	Drawing compound waste, wet	3.5 kg
<b>Energy</b>			
Energy	2.1 MWh <sup>(3)</sup>		
<sup>(1)</sup> This value is not an emission amount but the share of VOC input that is used for energy recovery by thermal or catalytic oxidation.			
<sup>(2)</sup> No representative emission values are available that allow for the calculation of specific emission factors. Single measurements have shown that concentrations of up to several thousand mg/m <sup>3</sup> are obtained. NO <sub>x</sub> and CO values are highly related to the increasing input of nitrogen compounds from the varnish systems (NMP).			
<sup>(3)</sup> The value strongly depends on the product (isolation) system.			

**Table: Mass balance from a plant producing medium sized winding wires**  
[12, UBA Germany, 2002] [54, BMLFUW Austria, 2003]

The second plant from which the consumption and emission data are shown in Table can be described as follows:

- installation F: produces fine wires, predominantly with a diameter of 0.08 mm, three shift operations over 320 to 340 days per year, typical capacity 30 t wire per line/per year.

Input		Output	
<b>Raw materials</b>			
Cu-wire (8 mm)	1100 kg	Product (Cu-wire 0.08 mm)	962 kg
		Wire residues (bare and coated)	138 kg
<b>Varnishes and solvents</b>			
Polymer in varnish	58 kg	Varnish on product	38 kg
		Polymer losses	20 kg
Solvents	186 kg	Solvents in waste	6 kg
		Catalytic oxidation of VOCs <sup>(+)</sup>	165 kg
		Emitted VOCs	15 kg
		NO <sub>x</sub> CO CO <sub>2</sub>	(=)
<b>Process materials</b>			
Water	~1000 kg	Water	~1000 kg
Wax	0.1 kg	Wax	0.1 kg
Drawing compound	0.3 kg	Drawing compound waste, wet	6.5 kg
<b>Energy</b>			
Energy	4.5 MWh		
<sup>(+)</sup> This value is not an emission amount but the share of VOC input that is used for energy recovery by thermal or catalytic oxidation. <sup>(=)</sup> No representative emission values are available that allow the calculation of specific emission factors. Single measurements have shown that concentrations up to several thousand mg/m <sup>3</sup> are obtained. NO <sub>x</sub> and CO values are highly related to the increasing input of nitrogen compounds from the varnish systems (NMP).			

**Table: Mass balance from a plant producing fine winding wires**  
 [12, UBA Germany, 2002] [54, BMLFUW Austria, 2003]

An installation for producing winding wire is made up of several machines. Usually the machines of an existing plant correspond to different technical grades that may have an influence on the overall emission from the installation. Important parameters in this context are:

- the technology applied at each single machine;
- the wire diameter that is produced;
- the quality that is produced.

Generally, fine wires are related to higher specific VOC emissions (calculated as g VOC per kg product) compared to thicker wires. This is due to the relationship product weight/product surface and to the achievable share of VOCs in varnishes and lubricants. To give an example: a wire with a diameter of 0.02 mm results in VOC emissions that are four times higher than that produced by a wire with 0.1 mm diameter. Analysis of recent measurements in fine wire and ultrafine wire installations shows a disproportionately high VOC emission from both lubricant application and from the enamelling process for specific application techniques with a very high solvent content. Nevertheless, the impact on the overall value of VOC emission seems to be negligible due to the very small percentage of these products compared to the total winding wire production tonnage.

The emission values in Table and Table show that these two existing installations cannot, at present, meet the limit values as specified in the Solvent Emissions Directive. It is important to know that the major share of the VOC emissions are due to lubricant application.

[40, EWWG, 2004] [12, UBA Germany, 2002] [38, TWG, 2004]

The process steps in the application of solvents are coating, including the curing of the coating, and the application of the lubricant.

### 9.3.1.1 Coatings

Table 9.3 shows the different coating systems applied and their average solvent content in relation to the type of winding wire produced. The coating systems that are marked with an asterisk (\*) contain n-methyl-pyrrolidone (NMP) as the volatile organic compound. For many years there has been an ongoing discussion with the supplier of NMP requiring enamel systems on replacing NMP with non-nitrogen solvent. This has been tried in different ways, but the results have not been technically acceptable up until now. For the mentioned insulation systems, the use of NMP is unavoidable today and in the near future according to enamel manufacturers. The market for the electromagnetic components using enamelled wires needs to be aware of the requirements of technical and security specifications, products for which the insulation has to meet the requirements of high thermal, mechanical and electrical performance specified in the thermal class.

**Table 9.3: Main winding wire products and applied coating systems**

Product	Insulating coating system	Share of total production (%)	Average solvent content (%)
Solderable round wires	Polyurethane	13	65–80
High temperature round wires	Epoxy, polyester, polyamide, polyimide, polyester-imide with additional polyamide-imide layers (*)	70	55–75
Self-bonding round wires	As above (first and second lines in this table) with additional bonding layers of aliphatic or aromatic polyamide (*)	11	55–75
Rectangular wires	Depending on temperature class: polyvinylacetal, polyester-imide, polyamide-imide with an additional bonding layer (*)	6	60–80
<b>Total</b>		<b>100</b>	<b>55–75</b>
* Coating systems may partially contain NMP (n-methyl pyrrolidone) as a VOC. Source: [12, UBA Germany, 2002] [38, TWG, 2004]			

The solid content of wire coatings usually varies between 20 % and 45 %; the remaining 55–80 % is organic solvent. For ultrafine wires, (with diameters in the ten micron range) high solvent contents of up to 75 % are necessary, whereas with increasing diameters of the wire-less solvent is needed in the coating application, i.e. around 55 %. The choice of solvent for the coating application depends on the coating type.

In order to achieve the required insulation performance, complex coating systems are usually made up of speciality polymers dissolved in special solvent blends. Organic compounds which are strong solvents (cresol/NMP) are required to dissolve the high molecular weight polymers (polyester-imide and polyamide-imide) and cannot be replaced by other solvents with lower solvency and less environmental impact. The most commonly used solvents within the industry are cresylic acids (cresols) with xylene used as diluent, naphtha or other aromatics, or NMP. These are all high boiling point/low vapour pressure solvents designed for production at high temperatures and therefore with very low evaporation rates at ambient temperatures.

Currently, a handful of possible coating technique alternatives have been developed:

- hot melt coatings;
- medium- and high-solids coatings;
- cresol-free coatings;

- waterborne coatings;
- electrocoat applicable coatings;
- two-component coatings;
- powder polyester coatings;
- UV curing coatings;
- extrusion coatings with thermoplastic materials.

However, for many reasons, such as lack of quality performance, as well as economical, technological or safety aspects, these alternatives have not yet succeeded against the classical winding wire coatings.

### 9.3.1.2 Lubricants

Several lubricants contain different volatile organic solvents; however paraffin (wax) is typically applied with an organic solvent content of 98–99.9 %. Alternatives such as concentrated lubricant emulsions, with a solvent content of between 50–95 %, water-based emulsions or solvent-free hot melts, are also used, however, with limited success.

### 9.3.1.3 Energy

[155, TWG, 2016]

The energy consumption in a winding wire manufacturing installation is purely electric. Electric energy is used for heating the curing ovens and running electric motors and ventilators. With the exemption of only one installation that produces ultrafine wires, all other installations reported specific energy consumption values of less than 5 kWh per kg of wire. A Swiss installation that produces ultrafine wires reported a specific energy consumption value greater than 10 kWh per kg of wire.

The main energy-saving efforts are focused on the enamelling process and on how the excess energy can be used. The main reported techniques for energy consumption reduction are:

- exhaust air heat exchanger in ventilation systems (enamelling process fans);
- air extraction and energy recovery from drying processes in oven and cooling;
- variable speed electric motors.

## 9.3.2 Emissions

[40, EWWG, 2004] [78, TWG, 2005]

### 9.3.2.1 Total VOC emissions

[155, TWG, 2016]

#### VOC, NO<sub>x</sub> and CO emissions

The values in Table are examples of measurements in a few installations that give an indication of current emission levels of VOC, NO<sub>x</sub> and CO:

	<b>M installations<sup>1</sup></b> (g/kg)	<b>F installations<sup>2</sup></b> (g/kg)
VOC	~8	~15
NO <sub>x</sub> <sup>3</sup>	~10	~12.5
CO	~8.5	~15
Note: <sup>1</sup> M installations: these are data from installations that produce medium sized wires (diameter of >0.1 mm). <sup>2</sup> F installations: these are data from installations that produce fine wires (with an		

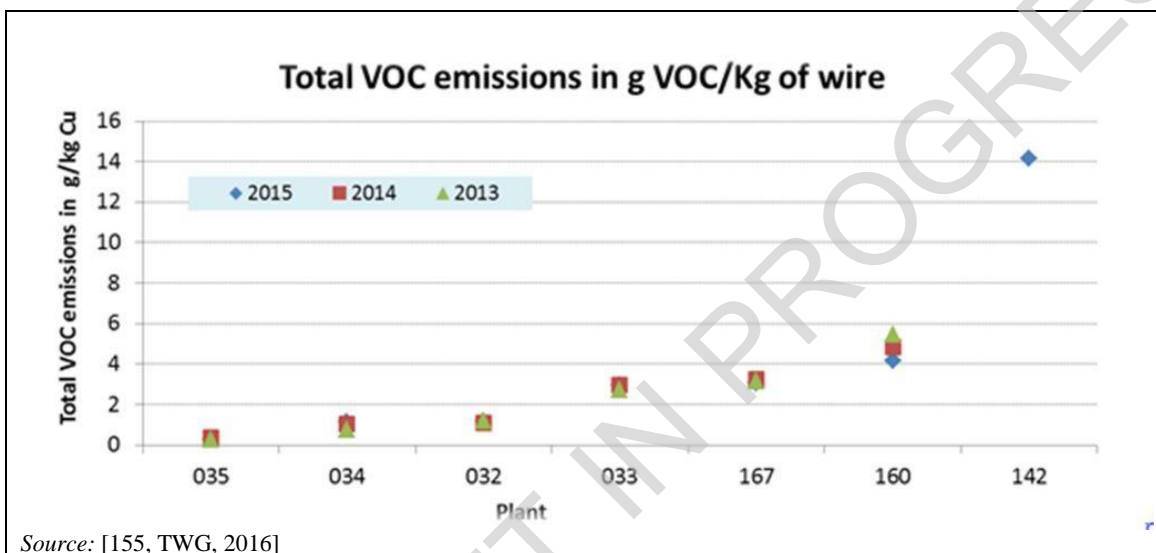
average diameter of  $\leq 0.10$  mm).

<sup>3</sup>There are no fine wire sites using exclusively NMP containing materials. The higher values are derived from measurements on production lines using exclusively insulation material containing NMP (see Section 3.3.2.1 and discussion on  $\text{NO}_x$  later in this section).

(See also Table 3.3 and Table 3.4.)

**Table: Examples of measurements of emissions to air**  
[40, EWWG, 2004]

VOCs are the main emitted pollutant for the winding wire manufacturing process. Figure 9.2 shows the reported total VOC emissions expressed in g of VOCs emitted per kg of wire.



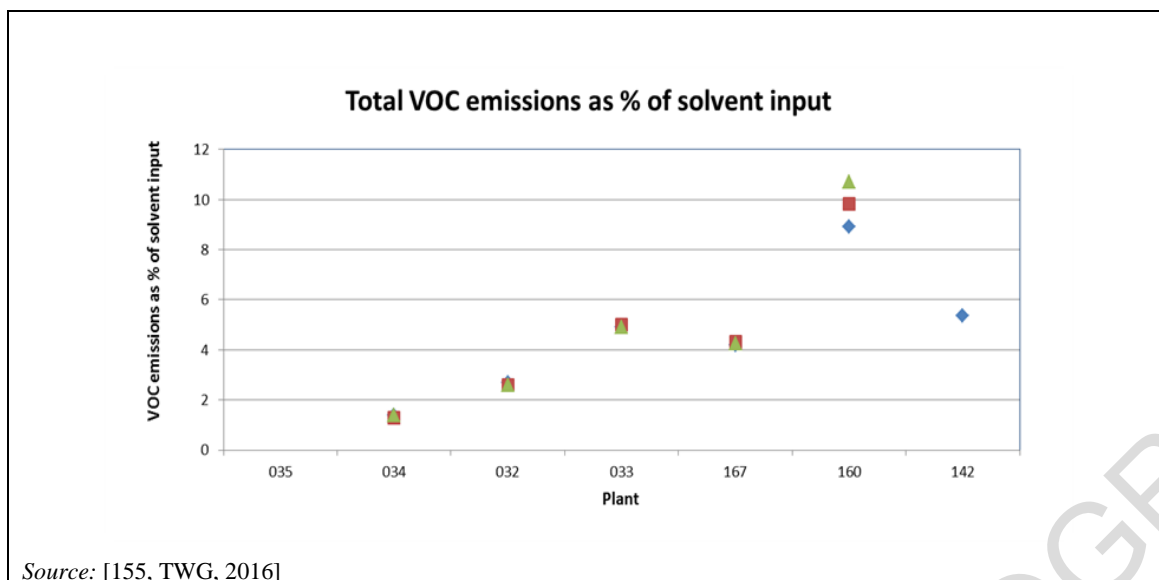
**Figure 9.2: Reported total VOC emission values (expressed as g of VOCs emitted per kg of wire) for the period 2013–2015**

It should be noted that Plant #142 in Switzerland is producing ultrafine wires (with diameters of less than 0.1 mm down to 0.01 mm and even below) where the specific emission values are expected to be higher than in thick wire production plants.

All reported values from plants producing thick wires or at least mixtures of fine (with diameters less than 0.1 mm) and non-fine wires (with diameters greater than 0.1 mm) are below the IED limit values of 5 g/kg of wire produced. Data from plants with a product mixture that contains thick, medium and thin (with diameters of less than 0.5 mm) show that specific emission values of the order of 3 g/kg are achievable.

In addition, for Plant #035, an emission limit value (ELV) of 0.5 g VOC per kg of produced wire applies according to its permit.

An alternative way of expressing VOC emissions is presented in Figure 9.3 where the VOC emissions are given as percentages of the total solvent input.



Source: [155, TWG, 2016]

Figure 9.3: Reported total VOC emission values expressed as percentage of the solvent input

### 9.3.2.2 Emissions to air in waste gases

#### 9.3.2.2.1 VOC emissions to air in waste gases

Reported values of VOC emissions expressed as total organic carbon in  $\text{mg}/\text{Nm}^3$  are presented in Figure 9.4.



Source: [155, TWG, 2016]

Figure 9.4: Reported values of VOC emissions to air in waste gases in  $\text{mgC}/\text{Nm}^3$  for the period 2013–2015

All submitted data with only one exception are below  $40 \text{ mg C}/\text{Nm}^3$ . The best performance occurs for the installation where regenerative thermal oxidation is applied in addition to the process-equipped catalytic oxidation of VOCs from the curing oven. Note this data refers to a sampling periodicity of once in three years.

#### 9.3.2.2.2 $\text{NO}_x$ and CO emissions

[155, TWG, 2016]

Very little data were submitted for periodic monitoring of  $\text{NO}_x$  emissions measurements with values varying from  $17 \text{ mg}/\text{Nm}^3$  up to  $470 \text{ mg}/\text{Nm}^3$ .



Many attempts have been made to reach a low level of CO and NO<sub>x</sub> emissions; however, running the enamelling machine efficiently and the destruction of VOC are given priority together.

*VOC emissions* At an EU 25 level for the year 2000 (according to the RAINS model), NMVOC emissions were 5.4 kt, representing 0.05% of total NMVOC emissions. Total activity was 420 kt of winding wire coated, and the average emission factor is about 12.3 kg NMVOC/t of wire coated meaning that emissions from this sector are already partly treated in EU25 (based on an unabated emission factor is 17 g/kg in 1990). VOC emissions are proportionately lower from the drying processes, due to the waste gas treatment. The major remaining source of VOCs is from the application of the lubricants. In Table, fine wires are produced by applying a final wax coating with white spirit. The white spirit dries off and consequently VOC emissions are higher. However, in the case of thicker wires, new low solvent techniques can be used. However, these techniques are not readily usable on fine wires of 0.01–0.1 mm (see Section ) [78, TWG, 2005].

Solvent emissions from the industry have been steadily reduced for over 40 years, and a baseline figure of 13 g/kg for 1995 has been estimated (when analysis of emissions started). The industry proposed a reduction target for emissions of 5 g/kg for wires with diameters of >0.1 mm by 2007 and of 10 g/kg for fine wires (with an average diameter ≤0.1 mm). This was based on an industry study using best practice technologies described in this Chapter and modified by experience of the difficulty of reducing the solvents used in fine wire production (for example, see Section 3.4.5.6). This equates to a reduction of up to 60 % (and up to 70 % compared with estimates of the situation in 1990). [20, Europacable, 1997]

#### *Oxides of nitrogen (NO<sub>x</sub>)*

See Section 17.10.8. [90, Tempany, 2006, 111, EWWG, 2005, 140, Tempany, et al., 2006]

NO<sub>x</sub> is produced as a result of the oxidation of VOCs in waste gases and give rise to the cross-media conflict between abating VOCs and creating NO<sub>x</sub>. One source of NO<sub>x</sub> emissions is the direct result of oxidation of the nitrogenated solvents used in the production of certain enamel systems (see). The concentration of NO<sub>x</sub> is proportional to the destruction of VOCs for the products that contain the nitrogenated solvents. Only a part of the nitrogen contained in NMP is converted to nitrogen oxides, at a ratio of 90 % NO and 10 % NO<sub>2</sub>. The other major source of NO<sub>x</sub> is the oxidation of atmospheric nitrogen during combustion of VOCs in the oven. When using enamels containing nitrogen, emission values of NO<sub>x</sub> can be well over 150 mg/Nm<sup>3</sup> depending on the specific airflow conditions in the enamelling machine and the number of machines using solvents containing nitrogen. In other cases with different airflows and NMP usage on process machines, the levels are 150 mg/Nm<sup>3</sup> and indistinguishable from satisfactory NO<sub>x</sub> levels associated with combustion (see the CWW BREF [67, EIPPCB, 2003]). This is a common problem for all installations over Europe. Enamels based on nitrogen-free solvents, such as polyvinyl-acetal, result in wires of low heat class, and do not meet the specifications required by the customers that the polyamide-imide products attain. NO<sub>x</sub> emissions after catalytic oxidation do not currently undergo treatment.

Table 9.4: Winding wires: Further examples of NO<sub>x</sub> emissions

Installation(s)	Group of 34 enamelling ovens	Group of 165 enamelling ovens	Installation 1 enamelling	Installation 2
<b>Short description</b>	Exhaust gases collected in three tubes leading to one stack (flue)  Special local conditions: industrial area, close to a power station	Exhaust gases collected by hoods over single sources in four stacks (flues), 35 - 50 m high  In order to avoid odour emissions (olfactory trouble with neighbourhood), a large amount of air from the production hall is extracted together with the gas from the oven  Sources are spread over an area of about 10000 m <sup>2</sup> Special local conditions: mixed industrial and residential zone (climatic spa)	80 % of all product lines used NMP during measuring period  Dilution of the exhaust gas in the hood: 1/10 from oven, 9/10 from hall  Estimation: 2/3 of the NO <sub>x</sub> is caused by nitrogen input (NMP), 1/3 caused by thermal process	Measurement on ventilator on the roof (ventilation of production hall and air from the cooling of the enamelling oven)  NO <sub>x</sub> emissions caused by small, uncontrollable process source.  Number of fans: more than 100, spread over the production area of 10 000 m <sup>2</sup>
<b>Volume flow (Nm<sup>3</sup>/h)</b>	3 700, 7 000, 34 500	53 600–98 000 in each of the stacks average mean value: 68 480	60–810	
<b>Temperature (°C)</b>	~ 80 gas temperature at the entrance of the stack	70–110 gas temperature at the entrance of the stack	250–550 temperature of undiluted exhaust gas at the source	30–45 temperature of air
<b>Concentration (mg NO<sub>x</sub>/Nm<sup>3</sup>)</b>	19 60 34	Average: 51.3	550–1 500 Average: 615	Average value: 12
<b>Mass flow NO<sub>x</sub> (kg NO<sub>x</sub>/h)</b>		Total: 14.07	Average: 0.0835 from a single source	Total: 4 mean single sources: < 0.040
<i>Source:</i> [140, Tempany, et al., 2006]				

The total amount of NO<sub>x</sub> emitted by the industry is estimated to be between 1 kt and 2.7 kt a year (based on 2000 EUROSTAT figures).

#### **Carbon monoxide**

CO is formed by the partial combustion of the enamel components during catalytic incineration in the enamelling machine. Carbon monoxide is a consequence of the destruction of solvent rather than of the burner efficiency. The concentration of carbon monoxide is dependent on the dwell time within the burner rather than the burner being incorrectly set. If the combustion efficiency is increased, the CO emissions would be reduced, but with a corresponding increase in CO<sub>2</sub> and NO<sub>x</sub> emissions.

An enamelling machine is not controlled according to CO emissions but under completely different conditions, and these are as follows:

- Ensuring the correct temperature within the enamelling machine in order to achieve the optimum properties from the enamel film. Increasing the burner temperature would require dilution air to reduce the temperature in the enamelling chamber overall. This would require a greater amount of energy and is not considered to be the best environmental option.

- Using excess air to prevent the lower explosive limit from being exceeded and so preventing explosions within the machine. Reducing the airflow to increase the residence time is, therefore, not an option.

Attempts have been made to limit the emission of carbon monoxide by using secondary catalysts; however, meeting the emission limits will remain an issue because of the relatively short life of the catalysts and the corresponding financial implications.

#### 9.3.2.2.3 Dust emissions

As the films applied to the wire are extremely thin (in the order of 10  $\mu\text{m}$ ) any dust present in the enamelling process would cause very serious surface quality problems. As any emission to the air is only a portion of the recirculated air, there will be no dust emissions expected.

With respect to the current consumption and emission values, there are no major differences in all the European countries because of the same machinery and the fully integrated abatement technique in all kind of enamelling machines.

#### 9.3.2.3 Emissions to water

The water used in a winding wire plant normally is used in closed circuits. Emissions to water from the enamelling process are low; however water use should be kept as low as possible and this is commonly done by:

- minimising the flow through cooling baths and recycling the water through filters and de-ionisers when practicable;
- using conductivity meters to optimise the treatment and conserve water in cooling towers;
- prolonging the life of waterborne wire drawing lubricant emulsions by using filtration, centrifugation where practicable and ensuring efficient management of the lubricant to prevent premature ageing by stagnation and bacterial degradation.

#### 9.3.2.4 Waste generation

[78, TWG, 2005] [155, TWH, 2016]

The main sources of waste are from the drawing process and in the enamelling stage of the winding wire production.

##### **Drawing**

- The drawing emulsion is used in a closed loop system, it is continuously cleaned using a paper filter or a hydrocyclone separator. In order to reduce waste amounts, emulsion treatment (reconditioning) is carried out with demineralised water; water is evaporated during the process and waste amounts are minimised.
- The filters of the drawing emulsion circuit contain a certain amount of copper particles from the drawing process. They are recycled externally for the copper content. Reported values for filter and paper waste generation indicate a waste quantity of the order of 5–8 t per year.

##### **Enamelling**

- Varnish application. In order to reduce varnish losses, the varnish is applied in varnish baths, during die stripping using the varnish circuit and by dosed varnish using felt application.
- Recycling of bare or enamelled wires. The production scrap (bare and enamelled wires) is recycled to 100 %.
- Used solvents, residual enamels and cleaning wipes containing solvent are collected and disposed of (usually by incineration).

The reported figures for generation of waste paint and varnish from the enamelling vary between 6 kg and 45 000 kg per year, with a specific value of 6–30 g of waste paint/varnish per kg of input solvent with only one exception (see Figure 9.5).

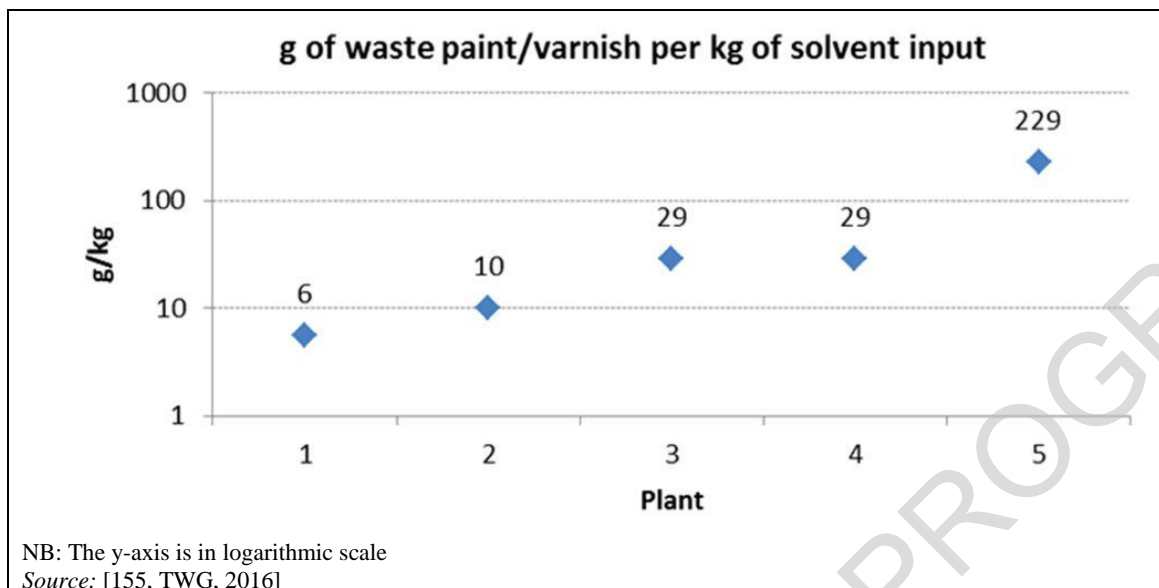


Figure 9.5: Specific waste generation values (g of waste paint/varnish per kg of input solvent) - Average values for the period 2013–2015

## 9.4 Techniques to consider in the determination of BAT in winding wire manufacturing

### 9.4.1 General techniques in winding wire manufacturing

[78, TWG, 2005]

In Chapter 17, techniques are discussed which might also be applicable to winding wire manufacturing. In Table 9.5, the general techniques relevant for winding wire manufacturing are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1, and the applicability is discussed in this section, below.

**Table 9.5: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

The EGTEI synopsis sheet for the coating of winding wires (see Annex 21.3.1) gives some data on the cost-benefit at a European level for some techniques to reduce VOC emissions. However, the EGTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as cross-media effects or the technical characteristics of individual installations and products. [82, EGTEI, 2005] [78, TWG, 2005]

~~Techniques described in the sub-clauses of Section 17.2.4 are not applicable in the winding wire manufacturing. The enamelling compound is supplied in the final state by the manufacturer of the compound according to the requested content of solvent and polymer; there is no mixing operation in the winding wire installation and no dilution or addition of solvents during the manufacturing process of the enamelled wires.~~

~~Section 17.7: Due to the specialist and integrated nature of the process equipment for the coating of winding wires (described in Sections 9.1, 9.2 and 9.4), the general techniques covering only single aspects are technically not applicable to the integrated winding wire machines.~~

~~Section 17.8: Drying is not applicable to winding wire installations, because of the industry specification for a high temperature for the enamelling process used.~~

~~Section : Substitution is not applicable because the mixture of the specified enamels cannot be modified without changing the mixture. The performance of the insulating layer is fixed in international standards and specified by the customers. All substitutions described in the sub-clauses of Section 9.4 were performed in close co-operation with the customers, most of them failed to meet the requirements as stated in the specific sub-clause.~~

~~Sections 17.10.2 to 17.10.7: The given techniques are not applicable to the winding wire industry. The waste gas treatment used in the in line process in winding wire installations is given in detail in Chapter 3. The industry specific enamelling machines do not allow the modification or replacement of some parts of the system. The gas loop in the driers is already optimised for recirculation and heat recovery, as well as VOC oxidation. The section on catalytic oxidation contains no additional information to this winding wire specific section. Biological treatment is not applicable because of the high waste gas temperatures.~~

~~Section 17.10.8: NO<sub>x</sub> abatement techniques notes that SCR and SNCR have not been applied to the winding wire industry for economical reasons. Water-based scrubbers would have to either be fitted to every oven/line or have a very large waste gas capture systems. They have not been applied in this sector and the quantities of NO<sub>x</sub> emitted do not currently appear to justify the technical and economic investment.~~

~~Section 17.11: Waste water treatment is not applied, because the only the drawing process is water based and uses a closed loop of the drawing emulsion.~~

~~Section 17.12.7 is not applied because of not using activated carbon.~~

~~Section 17.12.8 is not applied, because there is no waste water treatment in this kind of installation.~~

~~Section 0 and 17.13: Dust and odour abatement are already addressed by the in line machine technique.~~

~~Techniques to consider in the determination of BAT in the winding wire industry and attempts for substitution of techniques and materials are given in the following sub clauses (3.4.x).~~

### **9.4.2 Energy management**

#### **9.4.2.1 Integrated drying, curing and VOC oxidation**

(See Section 9.4.4.1.)

##### **Wire cooling with room air or exterior air**

*Conventional techniques have been deleted if they can no longer be considered BAT.*

*This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumption or emissions*

##### **Description**

~~After the drying and curing of the enamel coating, the wire has to be cooled down before the wire can be routed back for another layer of enamel or for applying the lubricant. Room air or exterior air can be used for this. During winter seasons, room and exterior air will usually be mixed to avoid condensation of water in the cooling system.~~

##### **Achieved environmental benefits**

~~Reduced energy consumption as room or exterior air does not have to be cooled or undergo any treatment before it can be applied.~~

##### **Cross-media effects**

~~No data submitted.~~

##### **Operational data**

~~Commonly applied in winding wire manufacturing.~~

##### **Applicability**

Applicable to new and existing plants and commonly applied in all European winding wire plants.

#### **Economics**

Very low cost technique.

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

No data submitted.

#### **Reference literature**

[12, UBA Germany, 2002] [28, EWWG, 2004]

#### **Conventional solvent-based processes**

*All conventional techniques have been deleted if they can no longer be considered BAT.*

*This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumption or emissions*

#### **Applying conventional solvent-based coating baths with die application and coating circuit**

*This technique has been removed*

#### **Applying conventional solvent-based coatings with dosed coating supply and felt application**

*This technique has been removed*

#### **Applying conventional solvent-based lubricants using felts**

*This technique has been removed*

#### **Conventional water-based emulsions**

*This technique has been removed*

### **9.4.3 VOC-reduced coatings and lubricants**

#### **Replacement of conventional solvent-based materials (substitution)**

These sections describe possible alternatives for conventional enamel coatings (see Sections and 0) and lubricants (see Section 17.7.2).

#### **9.4.3.1 High-solids enamel coatings**

##### **Description**

A solvent-containing lubrication step is avoided by using coating system that also contains lubricant (a special wax).

##### **Technical description**

During the last 20 years, the solids content in general has been increased from 30 % to about 45 % (resulting in a solvent reduction from 70 % to 55 %), and from 20 % to 30 % solid content for wire sizes finer than 0.10 mm. These are considered 'high-solid' coatings in the winding wire industry.

All plants in the EU are currently applying coatings with a solids content of at least 30 % for winding wires with diameters < 0.2 mm.

### **Achieved environmental benefits**

A relatively significant reduction in solvent emissions.

### **Cross-media effects**

A very high solids content requires additional high energy input for the production process and, therefore, a higher energy input for heating; however, more waste is produced.

### **Operational data**

A greatly increased solids content shows a tendency to inferior quality levels of insulation films; see Section 9. It is also more complicated to achieve the right thickness of each layer of the insulation. Experience shows a direct correlation between the solids content and the amount of scrap produced. Therefore, it was necessary to deliberately reduce the solids content because of the amount of material wasted.

### **Applicability**

Applicable to new and existing plants. May not be applicable in the production of fine wires.

### **Economics**

Limited cost benefit. Reduction of costs for the solvent in the enamels, but less energy is recovered from incinerating the solvents in the waste gas.

### **Driving force for implementation**

Cost reduction.

### **Example plants**

All plants are applying coating systems with +/- 30–45 % solids content.

### **Reference literature**

[28, EWWG, 2004] [38, TWG, 2004] [78, TWG, 2005]

## **9.4.3.2 Solvent-free lubricants**

### **Description**

Solvent-free lubricants can be applied with two systems:

- The wire is drawn through a lubricant-wetted felt.

A lubricant-impregnated filament is run with the wire and the wax melts due to the residual heat of the wire and the frictional heat.

### **Technical description**

Solvent-free lubricants can be applied by means of lubrication filaments or felts. Two alternative systems are in use in some factories: molten lubricant is applied to the wire surface by a lubricant wetted felt or by feeding the finished enamelled wire with a lubricant filament that melts due to the residual heat of the wire. The latter technique applies the lubricant by looping the filament two to three times around the enamelled wire and moving it in the same direction, although at a lower velocity.

### **Achieved environmental benefits**

Solvent emissions from lubrication are avoided. For non-fine wires, yarn can reduce VOC emissions to 3–4 g/kg product.

### **Cross-media effects**

Waste generation is created from used yarn, and, until now, there have been no possibilities for recycling.



**Operational data**

The lubricant is not a means of preservation for the winding wire but a well-defined means for specific performance of the wire required and approved by the customer. The application systems have to ensure that the small required amount of lubricant is homogeneously applied to the surface of the wire. ~~For typical values see Section 0.~~ Solvent-free lubricant application systems cannot be applied to wires less than 0.15 mm, because the friction generated between wire and lubricant is higher than normal, resulting in more wire breaks. Subsequently more scrap is generated when manufacturing wires less than 0.15 mm.

The quality requirements of the customer, regarding the thickness and evenness of the lubricant film, have to be recognised when dealing with solvent-free alternatives. The lubricant is usually specified by customers. Generally, it can be said that high quality requirements and thin wires are less appropriate for solvent-free lubricants.

There is also a need for supervision and maintenance of the application system and there is also a danger of malfunction. Compared to the conventional system, these alternatives are not effective or simple enough to be reliable.

**Applicability**

Applicable to new and existing plants. Most plants have some lines (although a few have up to 20 % of their lines) with solvent-free lubricant applicators. Until now, this technique has only been used for specific customers. General application of this is not possible these days because of customer requirements. This technique is applicable only to a restricted wire diameter range, i.e. 0.15–1.5 mm (i.e. not feasible for fine wires).

**Economics**

An economic gain is that solvents are omitted. The alternative systems using a soaked yarn has been under development already for several years. These systems require high investment costs for each line and have running costs comparable to the solvent solution. A break in the yarn will cause a large amount of scrap.

**Driving force for implementation**

Customers' requirements to use the alternative and to improve the working environment.

**Example plants**

No data submitted.

**Reference literature**

[12, UBA Germany, 2002] [28, EWWG, 2004] [38, TWG, 2004] [78, TWG, 2005]

**9.4.3.3 Self-lubricating coatings**

[ex Section 3.4.6.5]

**Description**

The external layer of the coating system also contains lubricant (a special wax).

**Achieved environmental benefits:** Solvent emissions from a separate lubrication step are avoided.

**Cross-media effects:** No data submitted.

**Operational data:** Current minor experiences show that this self-lubricating coating needs an additional application of a different lubricant to prevent friction during coiling operations.

**Applicability**

Until now, this technique has only been used for specific customers and it is under development in other places. General application of this is not possible these days because of customer requirements. For fine wire, the achievable coefficient of friction is worse than that of solvent-based systems. It could be a resolution for solvent emission problems within the next five years. However, this alternative is not applicable to flat wire manufacturing.

### **Economics**

There is likely to be zero impact as the enamel cost is higher but the cost of the solvent-based lubricant is eliminated.

### **Driving force for implementation**

Compliance with the Solvent Emissions Directive.

### **Example plants**

No data submitted.

### **Reference literature**

[12, UBA Germany, 2002] [28, EWWG, 2004] [38, TWG, 2004]

### ~~**Water-based enamel coatings**~~

*This technique has been moved to chapter 17*

### ~~**UV curing enamel coatings**~~

*This technique has been moved to chapter 17*

### ~~**Cresol-free enamel coatings**~~

*This technique has been removed*

### ~~**Powder polyester enamel coatings**~~

*This technique has been removed*

### ~~**Replacement of conventional solvent-based coating processes (substitution)**~~

~~These sections describe techniques where conventional enamel application systems are replaced by different systems (e.g. using different production machinery).~~

### ~~**Extrusion enamel coatings**~~

*This technique has been removed*

### ~~**Hot melt enamel coatings**~~

*This technique has been moved to chapter 17*

### ~~**2-component epoxy enamel coatings**~~

*This technique has been removed*

### ~~**Electrocoat enamel coatings**~~

*This technique has been removed*

**Self-lubricating coatings**

*This technique has been moved to chapter 0*

**9.4.4 Waste gas treatment****9.4.4.1 Integrated drying, curing and VOC oxidation****Description**

The liquid enamel layers on the metal wire need to be cured, for up to 30 times, until the desired layer thickness is obtained. The air/solvent mix resulted from the solvent evaporation process is treated in a catalytic oxidiser. The process heat from the catalytic oxidiser is used in the drying process to heat up the circulating airflow and/or as process heat for other purposes within the installation.

**Technical description**

This drying and curing process happens inside the enamelling chamber, which consists of a heated chamber (horizontally or vertically arranged) where the solvent is evaporated before moving into a higher temperature zone (> 400–700 °C) where the film is cured.

Recirculating airflow ovens are in use for contemporary wire coating processes. The direction of the circulating airflow can be with or against the direction of the moving wire.

**Achieved environmental benefits**

Integrating drying and curing with waste gas extraction and oxidation achieves:

- reduction of VOC emissions; and
- optimal energy recovery from the waste solvent.

**Environmental performance and operational data**

No specific measurement is available for the ratio between the energy input from external heating (gas or electricity) and from solvent-laden air. Plants estimations show that of 40 % of the total heat/energy used comes from the catalytic oxidation of the evaporated solvents.

In gas-heated machines, the solvent-laden air is passed directly into a gas burner, where the design of the burner allows adequate mixing with secondary (recirculated) air and oxidation occurs. To ensure that the solvent concentration does not exceed the lower explosive limit (LEL), it is important that excess air is supplied.

Using electrical heating, the solvent-laden air is passed over heating elements to reach a temperature of more than 500 °C. This is generally sufficient to support the catalytic oxidation. In all cases, electrically heated machines use precious metal catalysts. After thermal or catalytic oxidation of the solvents, the air stream is recirculated to provide complete or partial heating of the enamelling chamber. Exhaust gas velocities may be lower than in other industries to ensure a maximum energy efficiency balance from the use of recirculated air. It is important that any oxidation takes place where the air stream is recirculated. Oxidation in the stack will only produce hotter exhaust air.

Contemporary ovens in use for very fine enamelled wires work with heat transfer by radiation or a combined radiation and circulating air flow/convection.

The enamelling chamber is typically maintained under negative pressure to allow the capture of any fugitive emissions from the enamel supply system and to contain any degradation products or products of combustion from entering the workplace air.

**Cross-media effects**

Maintaining high VOC destruction rates is vital to guarantee conformity with VOC emission legislation as well as keeping the finished wire free of solvent residues. This main aim might conflict with the target to maintain low CO and NO<sub>x</sub> emissions

Input of nitrogen-containing enamels and the high temperatures at the catalysts could give rise to non-optimised CO and NO<sub>x</sub> emissions.

### **Technical considerations relevant to applicability**

Generally applicable in the winding wire industries.

Contemporary ovens in use for very fine enamelled wires work with radiation or a combined radiation and circulating airflow.

### **Economics**

A rough estimation of the purchase cost for a complete line gives a range from EUR 120 000 to EUR 250 000, and the average might be EUR 200 000 per line. This large variability is the result of the significant differences of machines in terms of size and layout. Any specific line design for specific wire sizes will be far from that average value.

### **Driving force for implementation**

- Local environmental legislation.
- Prevention of odours.
- Reduced operating space and time due to integration.
- Reduced costs for gas extraction and treatment due to integrated destruction of VOCs combined with energy recovery.

### **Example plants**

Implemented in all winding wire plants.

### **~~Waste gas from enamelling~~**

*This technique has been removed*

### **~~Lubrication~~**

*This technique has been removed*

## 10 COATING AND PRINTING OF METAL PACKAGING

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

### 10.1 General information

[159, MPE, 2017]

At a European level, the metal packaging sector comprises more than 300 sites employing more than 60 000 people across 26 countries with an annual production of over 100 billion units of rigid metal packaging per year<sup>25</sup>.

The metal packaging industry converts raw materials into metal containers and components which are supplied to the packer/filler who in turn supplies the retailers.

Metal packaging is manufactured from steel and aluminium, and is commonly referred to as cans, components and drums used for food and beverage processing, product protection and storage, and to facilitate transport. This packaging is used for a wide range of different products, for example:

- food and beverages;
- dairy products;
- paint;
- cosmetics;
- pharmaceuticals;
- chemicals;
- mineral oils.

Metal packaging has a variety of different manufacturing techniques but it can be summarised primarily into whether the container is formed first and then the coating and printing process application is carried out on the finished shape or whether coating and printing is performed on flat sheets before assembly into finished products.

The finished shape process is usually called coating and printing in the round and this covers industrial drums, beer and beverage cans and some aerosols. Coating and printing on flat sheets is the older process that covers a wider range of products. It is a more flexible system and a production unit may be a mixture of different techniques although some may require some protection repair as well. These are reflected in Table 10.1 where all the major techniques and products are listed.

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<sup>25</sup> Data taken from BCME and Empac websites in February 2016.

Table 10.1: Overview of manufacturing techniques used for coating and printing of metal packaging

Packaging Manufacturing Process		Substrate used	Solvent treatment applications						Typical Products, not a full listing		
			Spray	Roller Coating (coils, sheets and can externals)	Direct dip coating	Powder spray	Electro-coating	Compound lining		Printing	
Coating and Printing in the Round	2pc Wall-Ironed Cans	Steel	x	x	x			x	Food, Pet Food, Beverages		
		Aluminium	x	x				x	Beverages		
	Impact Extrusion	Aluminium	x	x				x	Aerosols		
	Industrial Drums	Steel	x	x				x	Industrial		
Coating and Printing on the Flat	C o n t a i n e r	Food: Grocery and General	Steel	x	x		x		x	Food, Pet-food, Beverages, Industrial, General Line,	
		Aerosols	Steel	x	x		x		x	Aerosols and some food applications	
		Industrial	Steel	x	x		x		x	Industrial, General Line,	
	Drawn Cans	2pc Drawn	Steel	x	x				*	Food	
			Aluminium		x					*	Food
	C o m p o n e n t s	Can Ends	Steel	x	x			*	*	*	Food, Pet-food, Aerosols, Beverages, Industrial, General Line, Ends and Closures
			Steel		x				*	*	Food,
		Closures	Steel		x				*	*	Beverages
			Aluminium		x				x	x	Beverages
	Crowns	Steel		x				*	*	Beverage	

Source: [159, MPE, 2017]

After the production of the container, it is then transported to the product manufacturer where the container is filled and then the correct type of component is mechanically connected to the container, thus producing a filled package.

At a European level, the metal packaging sector comprises more than 260 sites employing more than 40000 people with annual sales of EUR 7000 million. The metal packaging industry converts raw materials into metal containers and components which are supplied to the packer/filler who in turn supplies the retailers.

Metal packaging is manufactured from steel and aluminium, and is commonly referred to as cans, pails and drums used for storage of products, protection and to facilitate transport. Metal packaging includes domestic containers of less than 25 litres capacity and industrial containers (drums) with more than 20 litres capacity. This packaging is used for a wide range of different products, for example:

- food, e.g. preserves, soups and drinks
- paint
- cosmetics
- pharmaceuticals
- chemicals
- oils
- tobacco
- lids for jars and bottles
- aerosols.

There are four key manufacturing processes that are carried out within this sector and one or more of these, together with associated sub processes, may be carried out within a specific installation. These are reflected in Table.

<b>Metal packaging manufacturing processes</b>	<b>Information</b>
Two piece canmaking	<ul style="list-style-type: none"> <li>draw and wall iron (DWI) can manufacture. Coating and printing is mainly carried out by the dry offset process</li> <li>easy open end manufacturing. Spray coating is applied to steel ends</li> </ul>
Metal packaging manufactured from flat sheet	<ul style="list-style-type: none"> <li>flat sheet coating and printing. Primarily roller coating and lithographic printing (wet offset)</li> <li>three piece can manufacture. Protective coating applied to the side seam</li> <li>end manufacture (non easy open ends and easy open ends). Sealant is applied to the curl of the end in preparation for assembly to the can</li> </ul>
Impact extruded aluminium tube manufacture	<ul style="list-style-type: none"> <li>monobloc aerosols and collapsibles</li> </ul>
Drums	<ul style="list-style-type: none"> <li>drum manufacture</li> <li>external and internal protective coating applied mainly by spraying but also roller coating and lithographic printing (wet offset)</li> </ul>

**Table: Overview of the metal packaging manufacturing techniques**  
[38, TWG, 2004]

**Error! Reference source not found.** gives an overview of the techniques used for coating and printing in the different sectors of the metal packaging industry.

Surface to be treated	DWI	Sheet for ends, cans, components	Three piece cans	Components			Extruded aluminium tubes	Drums
				NEOE	EOE	Caps/closures		
1) Coating (protection)								
Roller								
— All over coating	*	*	* <sup>‡</sup>				*	
— Spot coating		*						
Spray	*		* <sup>‡</sup>		*			*
2) Printing (decoration)								
— Dry offset	*						*	
— Lithography (wet offset)		*						
3) Compound lining (Sealing)				*	*	*		*
Typical applications	Drinks, food, aerosol	Intermediate product for fabrication of ends, cans, caps and closures	General line food, drinks, aerosol	Three piece cans	Two and three piece cans	Drinks food-in conjunction with jars and bottles	Aerosol collapsible tubes for pharmaceuticals and cosmetics	Products from industry
Notes: *side stripe NEOE: non easy open ends; EOE: easy open ends; DWI: 2 piece cans								

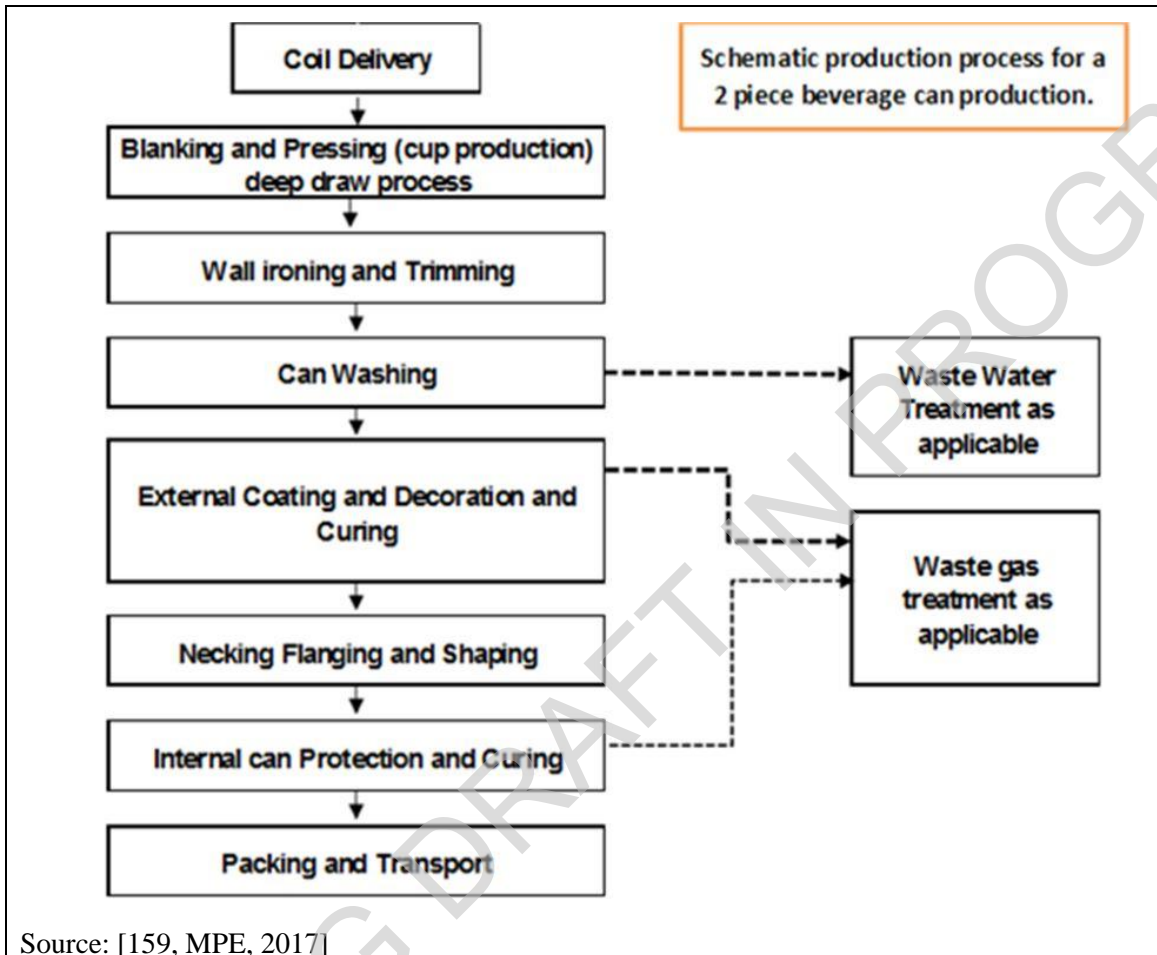
**Table: Techniques used for coating and printing of metal packaging**  
[38, TWG, 2004] [78, TWG, 2005]

## 10.2 Applied processes and techniques in the coating and printing of metal packaging

[159, MPE, 2017]

### 10.2.1 Two-piece can manufacture (draw and wall iron - DWI)

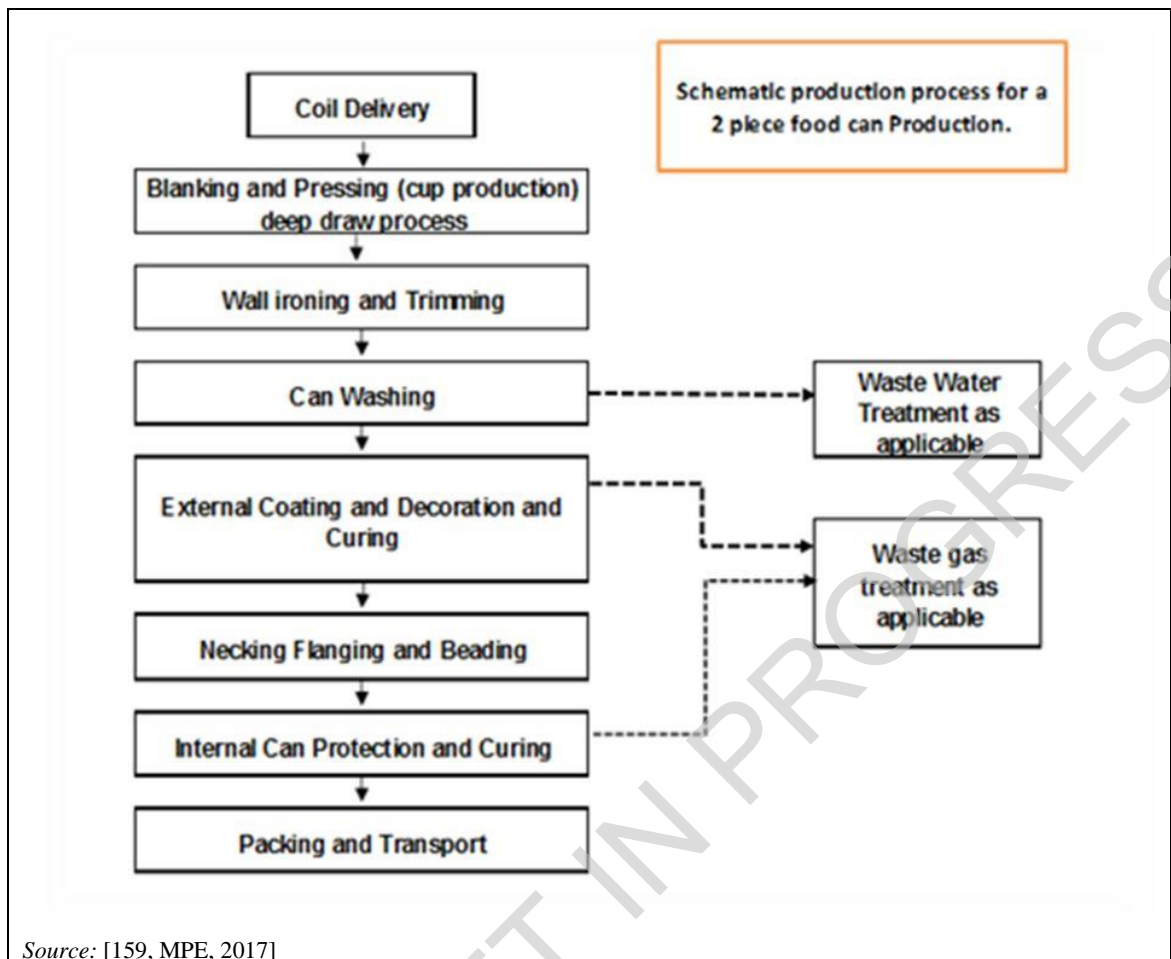
Figure 10.1 shows the schematic production process for beverage cans.



Source: [159, MPE, 2017]

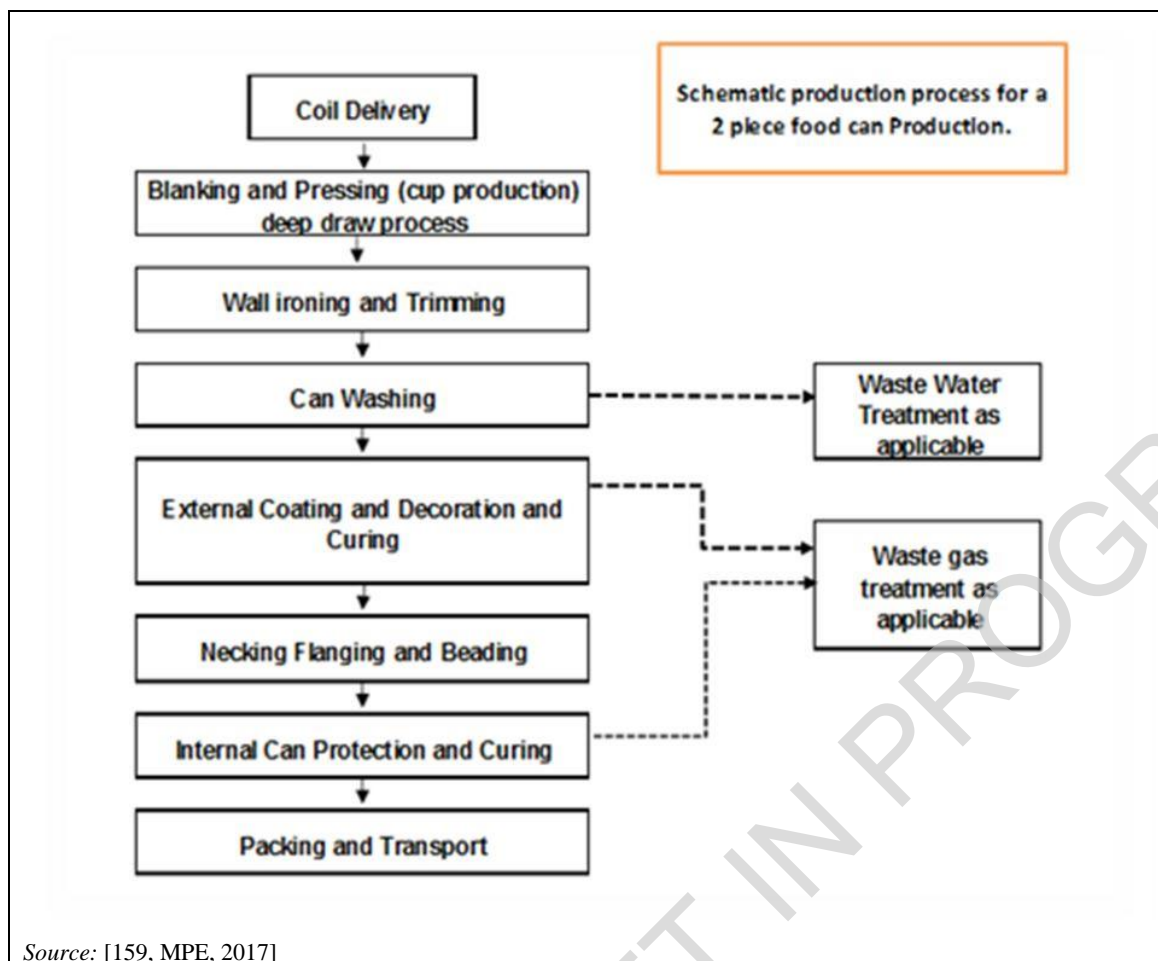
Figure 10.1: Production process for beverage cans





Source: [159, MPE, 2017]

Figure 10.2 shows the schematic production process for food cans.



**Figure 10.2: Production process for food cans**

The following generic description covers the manufacture of beverage cans, which normally carry an external printed design, and food cans, which are usually finished with a colourless clear external coating and not printed. The entire process including conveying between the process stages is fully automated.

Aluminium or tinplated packaging steel is supplied in continuous coil strips and fed automatically through a mechanical cupping press where blanks are stamped and deep-drawn into cups.

The cups are conveyed to the body makers (long-stroke horizontal presses) where the cup walls are elongated by wall ironing and the bottom profile is formed. Immediately after wall ironing, the surplus metal of the can wall length is trimmed off so a fixed-height can is attained. Scrap arising from the blanking and trimming operation is recovered and recycled.

The metal-forming operations use a waterborne synthetic coolant with an added lubricant plus a small amount of biocide, both subsequently removed in the can washer. There is also the possibility of tramp hydraulic oil from the presses mixing with the coolant. The coolant is in a closed loop system where it is filtered, treated and reused.

Cans exiting the trimmer are then conveyed into a can washer where the excess lubricant is cleaned off. This can washing process differs for aluminium and steel substrates.

Steel cans are first cleaned with water by passing repeated spray stations in a reverse cascade arrangement, then rinsed with demineralised water and finally dried in a natural-gas-fired oven.

Aluminium cans follow the above sequence with the additional stage of pretreatment using acid or alkaline aqueous solutions before rinsing with demineralised water. A mobility enhancer may be applied before the aluminium cans are finally dried in the oven.

The water treatment in the metal packaging industry is not directly connected to the surface treatment with organic solvents and therefore is not considered to be part of the STS BREF but rather another BREF (STM).

Food cans which are normally not decorated require a clear external protective coat applied to the upturned can via a curtain coater or wash coat system, between the last can washer stage and before the drying oven. The coated cans then have a period of drainage, before entering the oven to dry them and cure the external coating.

The external curtain/wash coat system is a recirculating system with the process designed to collect as much of the excess coating as possible.

Waste water from the can washer, demineralised unit and the wash coat is treated prior to discharge. There is a natural carryout of water via the wet cans entering the oven.

For aluminium, the waste water from the can washer is treated before discharge and the cleaned treated water can be recycled to substitute fresh make-up water.

Waste hot air from the can cleaning and drying is emitted directly to the atmosphere via an exhaust stack.

After cleaning, the cans are next passed automatically for external decoration. Usually the first step is base coating (but not always), followed by a second decoration step. The base coater applies either a coloured or clear layer of lacquer via a roller offset process onto the rotating can. The cans are then fed through a thermal convection oven.

After the curing of the base coat, the cans are transferred to the decorator (printing machine) where the decoration is applied by using printing inks in a dry offset process. If an over-varnish is required, it is applied as the last stage (wet-on-wet), directly by a roller offset process on the decorator.

Aluminium cans are usually coated on the external bottom rim by another set of application rollers. This operation is carried out before the can enters the decorator oven and the rim varnish is cured together with the inks and the optional over-varnish in the oven.

After the external coating and printing is completed the can would normally undergo the necking, flanging and any shaping operations to give the final can appearance. The cans are first conveyed to the necker/flanger, which reduces the neck diameter of the cans to accept the ends. The neck-forming operation is supported by compressed air and small amounts of synthetic lubricants are used.

Steel cans are usually spray coated on the external bottom prior to the inside spray application for rust protection. This bottom coat dries at room temperature. The inside of the can is then coated with an airless spray technique using water-based materials. A set of nozzles sprays the lacquer into the rotating can ensuring that the desired film weight distribution is achieved. The cans are then passed through a thermal oven where both the inside lacquer and the bottom spray receive the final cure.

After each lacquering operation, the cans immediately pass into a gas-fired oven at typical drying temperatures of 180–200 °C. The emissions of the curing process are collected and exhausted by fans to the atmosphere or to abatement equipment.

Food cans have an additional forming operation of beading that has two parts. There is a rolling bead which is done to allow the can to roll through industrial food process and there is a single bead placed near the base of the can to assist in pressure resistance through the industrial cooking process.

Finally, prior to palletising, all cans must pass through a light tester and camera for inspection. Any potentially damaged product is rejected.

The following generic description covers the manufacture of beverage cans, which normally carry an external printed design, and food cans, which are normally finished with a colourless clear external coating and not printed. The entire process including conveying between the process stages is fully automated.

Aluminium or packaging steel is supplied in continuous coil strips and fed automatically through a cupper, a mechanical press where blanks are stamped and deep drawn into cups. The cups are conveyed to the body makers, long stroke presses where the cup walls are elongated by wall ironing and the bottom profile is formed. Immediately after wall ironing, the excess metal of the can brim is trimmed off.

The metal forming operations use a waterborne synthetic lubricant plus a small amount of biocide, both subsequently removed in the cleaner. There is also the possibility of tramp hydraulic oil from the presses mixing with the lubricant. Excess lubricant is treated and re-used in a closed loop system. Scrap arising from the blanking and trimming operation is recovered.

Cans exiting the trimmer, which are loaded with lubricant and debris, are then cleaned. This process is different for aluminium and steel substrates. Steel cans are cleaned with mains water by passing spray stations in reverse cascade arrangement, then rinsed with demineralised water and finally dried in a natural gas fired oven. Aluminium cans are cleaned in a similar way. Additionally, to provide an etched surface needed for inking operations, aluminium cans are then pretreated using acid or alkaline aqueous solutions before rinsing with demineralised water. A mobility enhancer may be applied before the aluminium cans are finally dried in the oven.

Waste gas from the can cleaning and drying is emitted directly to the air via an exhaust stack. Excess water from the cleaning process can be recycled to substitute town water. There is a natural carryout of water via the wet cans entering the oven. Waste water from the aluminium cleaner is treated before discharge.

Where cans should not be decorated, which is the normal case for food cans, a clear external protective coat is applied to the upturned can via a curtain coater, between the can cleaner and drying oven. The coated cans then have a period of drainage, before entering the oven to dry them and cure the external coating. The external wash coat system is a recirculating system with the process designed to collect as much of the excess coating as possible. Waste water from the can cleaner, deioniser unit and the wash coat is treated prior to discharge.

After cleaning, the cans are passed automatically for external decoration. This consists of either base coat and ink on top or ink and over varnish on top. In the base coater, the can walls are coated with either a coloured or clear layer. The lacquer is applied via a roller offset process onto the rotating can. The cans are then fed through a thermal convection oven.

After the curing of the base coat, the cans are transferred to the decorator (printing machine) where the decoration is applied by using printing inks (typically containing 25–40% organic solvents) in a dry offset process. If an over varnish (typically containing 15–50% organic solvents) is required, it is applied as a wet on wet organic solvent, directly after printing on the same machine by a roller offset process. Aluminium cans are usually coated on the external bottom rim by application rollers. This operation is carried out before entering the decorator oven where the rim varnish is cured together with the inks and the optional over varnish.

The cans are then conveyed to the necker, which finishes the necks of the cans to accept the ends. The neck forming operation is supported by compressed air and small amounts of synthetic lubricants are used.

For rust protection, steel cans are usually spray coated on the external bottom prior to the inside spray application. This bottom coat dries at room temperature. The inside of the can is then coated with an airless spray technique with materials containing 15–20% organic solvents. A set of nozzles sprays the lacquer into the rotating can such that the desired film weight distribution is achieved (typically a thickness layer of 5–15  $\mu\text{m}$ ). The cans are then passed through a thermal oven where both the inside lacquer and the bottom spray receive the final cure.

After each lacquering operation, the cans immediately pass gas fired multiple zone ovens at typical drying temperatures of 180–200 °C. The emissions of the curing process are collected in a duct and exhausted by fans to the air or to abatement equipment. In general, the volatile gases created in the lacquer application machines are captured as well.

Finally, prior to palletising, all cans must pass through a light tester and camera for inspection. Any with potential damage are rejected.

Drying of the applied coating layers takes place in convectional driers at temperatures of 180–200 °C. The waste gases containing VOC from driers and also coating application units are generally treated via regenerative, thermal combustion. The process heat can be used via heat exchangers, e.g. for the cleaning process.

### 10.2.2 Impact extrusion of aluminium for aerosols and collapsible tubes

The production process of extruded aluminium tubes is shown in Figure 10.3.

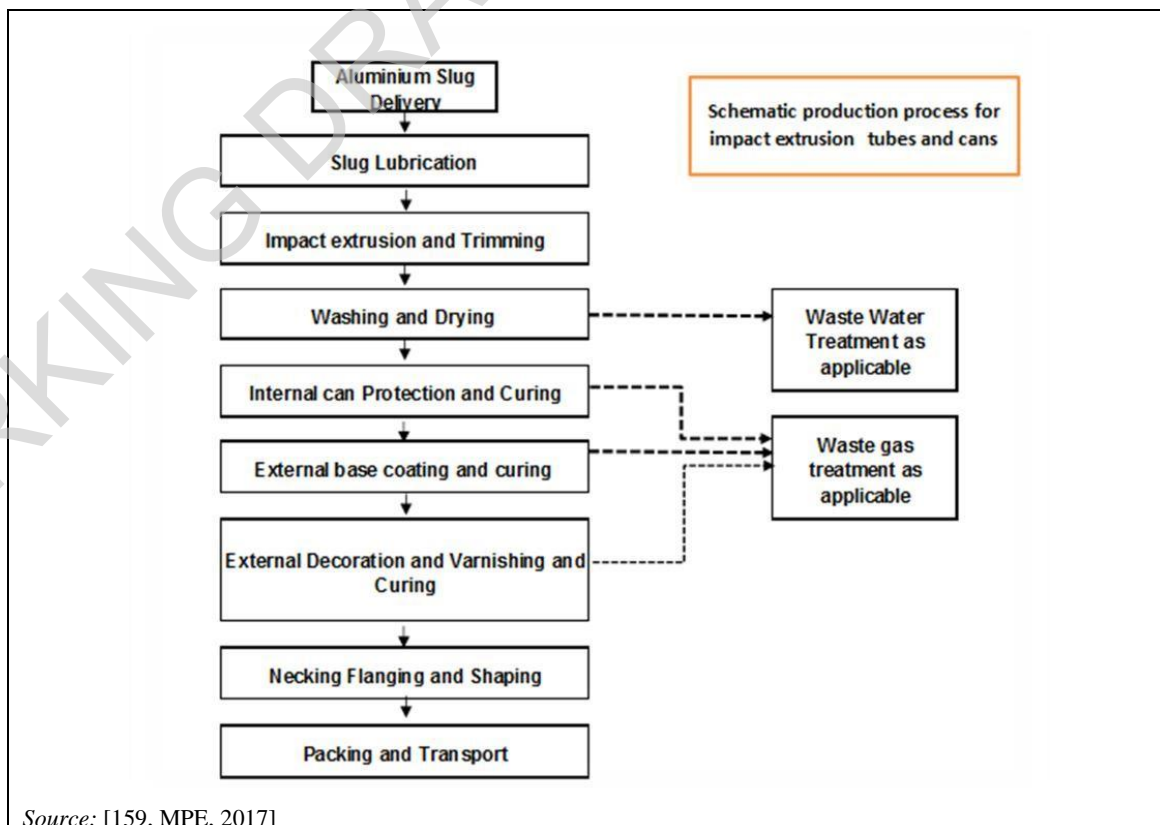


Figure 10.3: Production process of extruded aluminium tubes

In concept, this process is very similar to two-piece can making. The difference is primarily in the draw and wall iron (DWI) metal-forming process where the initial aluminium coil is 'thinned' to form the container; this process extrudes an aluminium slug into a finished container with a constant wall thickness.

Aluminium slugs, which are 99.5 % pure aluminium, are lubricated and then converted through a series of high-impact drawing operations into a tube with a single open end. The open end is trimmed to produce the required cylinder height and the produced trim is collected for recycling. Further separate metal-forming operations may inwardly dome the closed end for pressure resistance (aerosol), perforate it for later addition of a plastic screw thread and cap or further form it into a screw thread (the latter two for collapsible tubes).

The formed can is then cleaned in a continuous washer to remove residual lubricant. The chemicals used in the cleaning and etching process comprise caustic-based anionic detergents. The contaminated waste water may be discharged partly or totally to a sewer and/or reused to feed the caustic scrubber system described below as a means of fume abatement.

The inside of the can is then coated with an airless spray technique using solvent-based or water-based materials. A set of nozzles sprays the lacquer into the rotating can ensuring that the desired film weight distribution is achieved. The cans are then passed through a thermal oven where the inside lacquer is cured within the oven.

The cylinders are then transferred to a base coater whereby a metered coating of clear or pigmented base coat is applied by a roller using either a gravure or a conventional metering roller system with the rotating cylinder. The typical base coats are solvent-based but water-based coatings may also be used. Air from the coating station is extracted by fan and generally ducted to the air via high stacks. From the base coater, the coated cans pass automatically into a drying/curing oven, from which the extracted air is collected and discharged directly via high stacks or directed to abatement equipment.

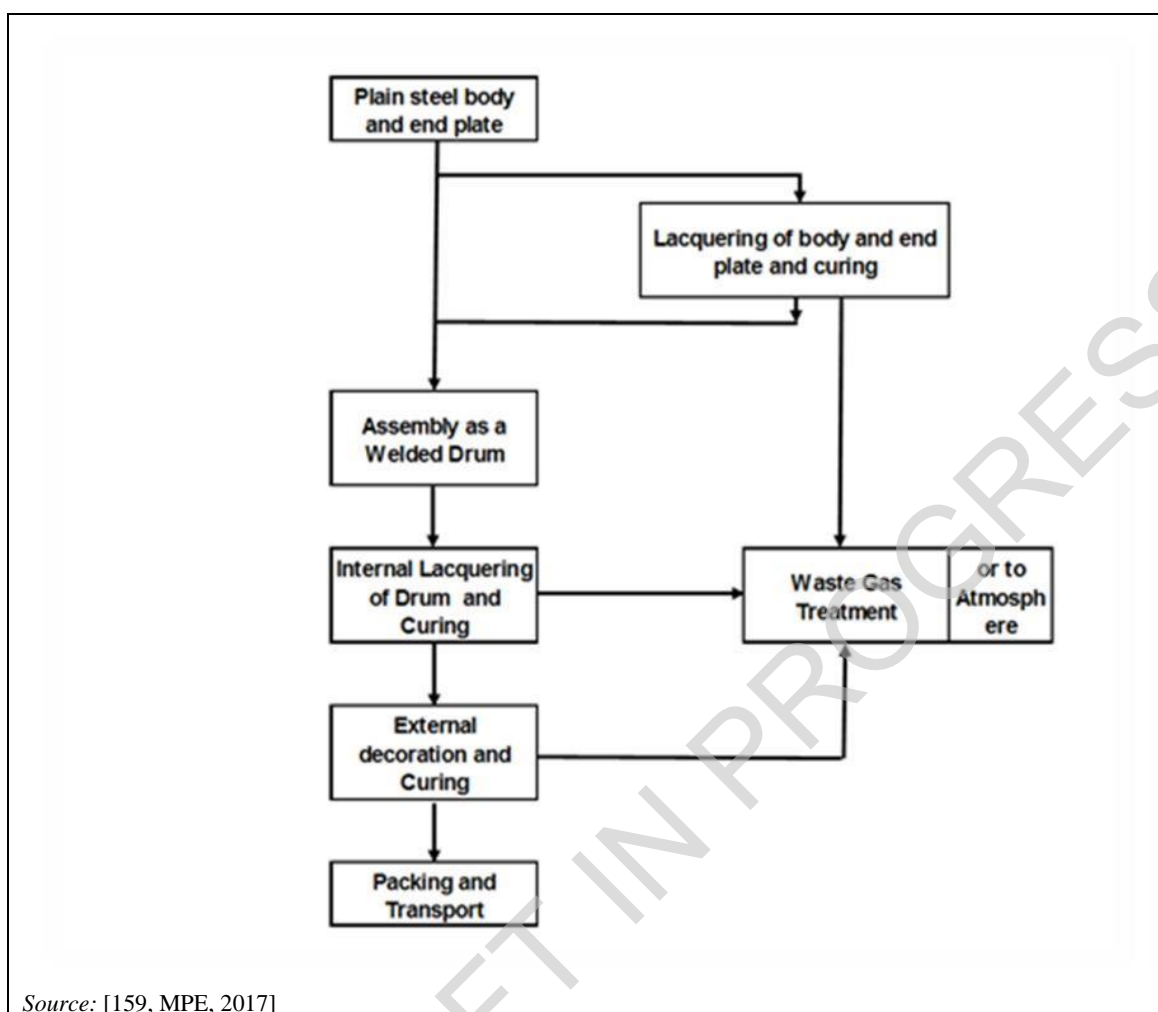
The cured base coat provides the key for the subsequent printed design, which is applied via a multicolour decorator using the dry offset process. A protective over-varnish is applied as the final operation before the cylinder passes automatically into an oven for drying and curing. The containers are usually coated on the external bottom rim by another set of application rollers. This operation is carried out in the decorator oven. There is fume extraction from the decorator, which is ducted to the air, having passed through a caustic scrubber, and separate extraction of the oven exhaust directly to the air or to abatement equipment.

For aerosol cans, the cylinder undergoes further reforming, with controlled application of a mineral lubricant, to 'neck-in' and curl the open end to accept the valve assembly which will be fitted subsequently to filling. Body shaping can also be undertaken prior to the final neck and curl operation for certain aerosol products.

The aerosol container is now tested for any leaks in a light tester and then sent to the packing station.

### 10.2.3 Industrial drums

Steel drums are manufactured primarily for industrial use. The principle of manufacturing drums is similar to the three-piece can manufacturing process (see 10.2.5). This is shown in Figure 10.4.



**Figure 10.4: Production process of drums**

Whether or not a drum will be internally coated depends on the goods that will be packed into the drums. Thus, internal coating is not limited to food-related use of drums but will also be done for chemicals that should not come into contact with the steel.

The drum body is welded out of a sheet of plain steel and the top and bottom panels are produced separately on cutting and forming lines. If required, these formed drum bodies and ends are separately coated with internal lacquer and cured. In the seaming machine, the assembly of the drum takes place. During this step the seaming compound is applied, when this has not already been done on the tops and bottoms in a separate process step.

After seaming, the drum is coated on the outside with external drum paint and the coating is cured (simultaneously with the seaming compound). As a final step, drums can be further decorated by screen printing or other printing techniques. Inks used in that process are usually solvent-based, but UV curing techniques are also used.

Internal drum coatings are generally applied via rotation discs (for the body) or by hot airless spraying. The majority of internal coatings are solvent-based because of the required chemical resistance between the steel and the contents and contain 45–60 % organic solvents. External drum paints are generally applied by hot airless spraying. These are mainly solvent-based and contain around 45–50 % organic solvents. In specific cases, water-based external drum paints are used, containing less than 10 % organic solvents. VOC process emissions are treated by abatement techniques prior to discharge.

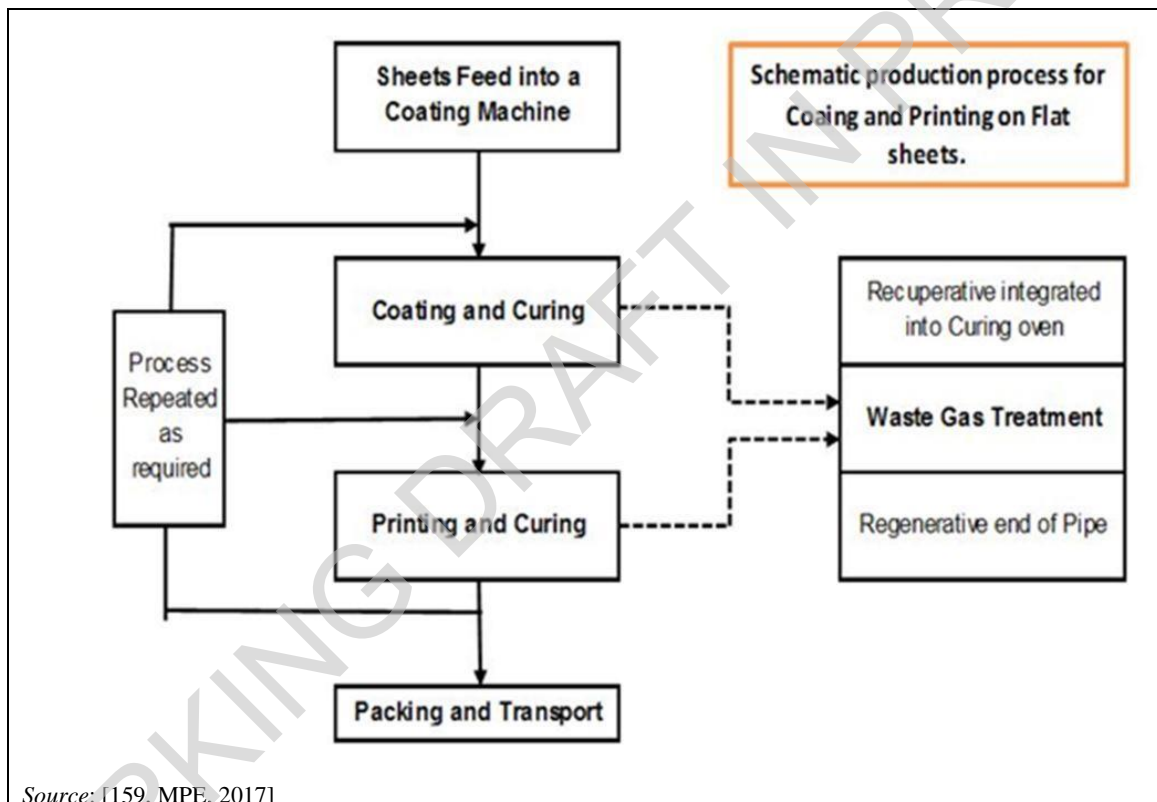
### 10.2.4 Flat sheet coating and printing

Flat sheet coating and printing operations can be split into four stages (not all of these operations are applicable in every case):

- internal coating;
- external base coat or size coat, however conventional print can be directly applied to tinplate;
- printing;
- varnish or top coating.

Curing of solvent-based coatings and inks takes place in thermal ovens usually at rates of up to 6 000 sheets per hour at temperatures of between 150 °C and 210 °C. Speeds and temperatures are dependent on sheet sizes, thickness and the coating specification.

Flat sheet coating and printing is the first separate and distinct operation necessary for the subsequent operations for the manufacture of three-piece and drawn cans, ends or caps and closures. This is shown in Figure 10.5.



**Figure 10.5: Production process for flat metallic sheet**

The substrate materials used in the flat sheet printing and coating process are mainly tinplate, electrolytic chromium-coated steel (ECCS), cold rolled steel or aluminium. The material is received either as stillages of pre-cut sheets or as coils which have to be processed on site into cut sheets first.

Metal sheets may pass through the printing and coating lines several times as multiple coating and decorative applications and curing passes are sometimes required. Different coating sequences are undertaken and are related to the product being packed.



The coating material is transferred onto a synthetic coated applicator roller and then transferred onto the sheet in a pressured contact method. The film weight is controlled by different techniques that optimise the coating flow onto the applicator roller. Any potential transfer of coating onto the bottom cylinder is removed whilst the machine is running by a scraper, to prevent contamination of the underside of the sheet.

On the printing lines, ink is transferred through a series of flow control rollers to give the correct application rate onto an application blanket to achieve the desired depth of colour. The printing techniques commonly used are wet offset, dry offset and, in some cases, a waterless lithographic process.

Periodic cleaning of the coating and print applicator rollers is required to remove the build-up of coating and ink constituents. At changeovers, more thorough cleaning of the coating and printing machines is carried out using various organic solvents, including reclaimed solvents, either manually or automatically. The waste organic solvent is often distilled and rebled either on or off site.

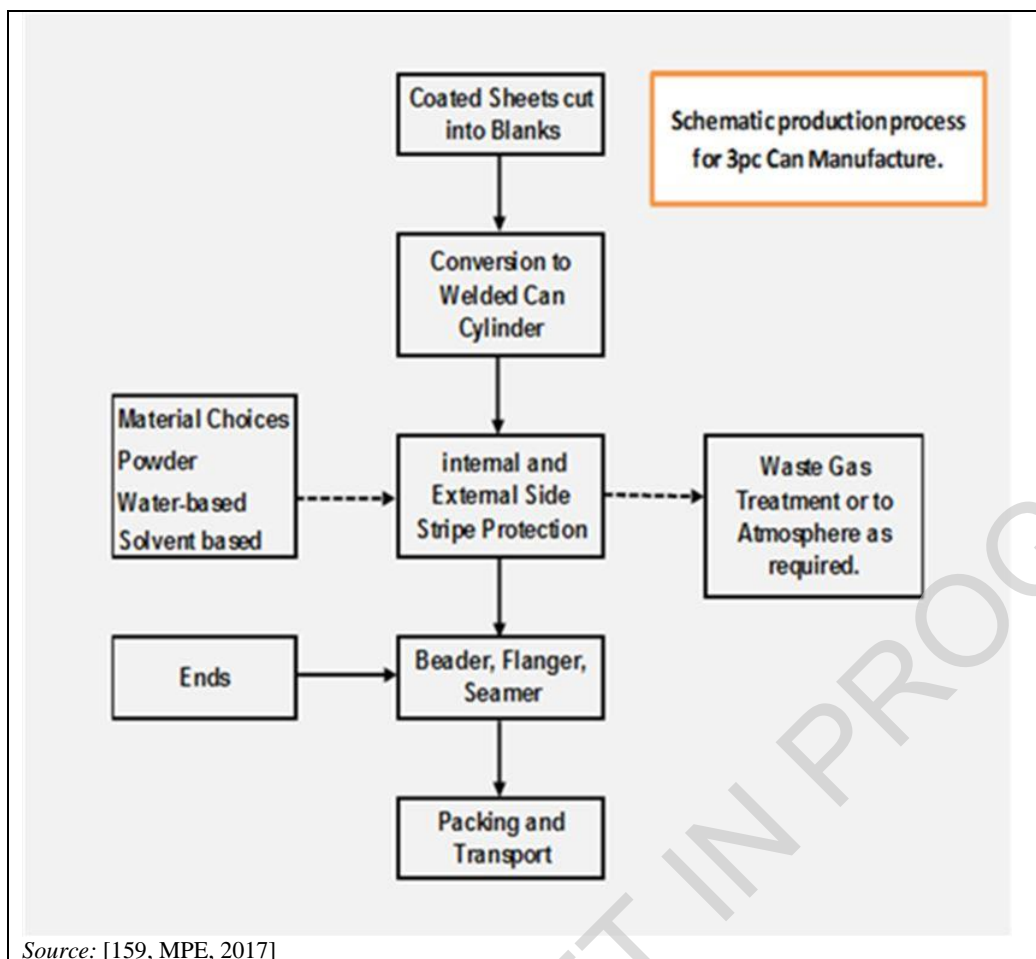
The coated or printed sheet is then transferred to the thermal curing oven where it is heated to the required curing temperature. VOCs from the organic solvent used in the materials applied are collected from the oven and the machine hoods with ducts and exhausted by fans to the atmosphere or sent to the abatement equipment.

Following this, the cured sheet is cooled with ambient air. This reduces the materials sticking together and the stack of sheets is rebuilt onto stillages for subsequent transfer to the next stage of the process.

Where UV curing inks and coatings are used, UV lamps are employed. This does not release VOCs but creates an extremely low level of ozone (ppm) which is exhausted to the atmosphere.

### **10.2.5 Three-piece can manufacture**

Three-piece cans can have a variety of seam constructions; however, welded is the most common across different product sectors. The production process for welded three-piece cans is shown in Figure 10.6.



**Figure 10.6: Production process for three-piece cans**

Three-piece can manufacture covers diverse products such as food cans, paint cans, industrial oblongs and aerosols. Tinplate sheets which have been previously coated and/or decorated, as described earlier in Section 10.2.4, are slit into individual body blanks. These body blanks are usually automatically fed, but sometimes manually fed, into a welding machine that rolls the body blank into a tube and then welds it along its length to produce a straight-sided welded cylinder. During slitting, the excess tinplate is trimmed off and subsequently recycled. An alternative means of joining the side seam is by mechanical clinching. In some cases, the circular cylinders can be reformed into other shapes, e.g. rectangular industrial oblongs.

Immediately after welding and while still on the welding machine, the internal and external surface of the weld may have a protective coating applied depending on the specification of the three-piece can being manufactured. This protective coating is called a side stripe and may either be a solvent-based, a water-based or a powder coating, depending on the intended end use of the container. In the case of side stripe lacquers, these are applied using: rollers or airless spray guns on the internal, spray guns, brushes and rollers on the external face. Any overspray is collected and ducted to the air. In the case of powder coatings, these are applied electrostatically and any overspray is collected and recycled.

Following welding / side stripe application, the cylinders pass through an oven to cure the applied side stripe. The oven types are generally either hot air or induction and apply a localised heat to the weld area of the cylinder. Emissions from the side striping oven are in most cases emitted directly to the air via exhaust stacks and sometimes are extracted to the abatement system.

Following side stripe curing, some specifications of three-piece cans (typically food cans) are then automatically fed into a beading machine so that strengthening beads can be fabricated into the body wall of the cylinder. This process is purely mechanical and requires no additional process materials. Depending on the can specification, after beading or side stripe curing, the welded cylinders are automatically fed into either necking and/or flanging machines so that both ends of the cylinder can be profiled ready to accept the end component.

The fabricated body is then automatically passed to an end-seamer where the end component, previously manufactured, is fed and seamed onto one end of the fabricated cylinder. The necking, flanging and seaming operation is also purely mechanical and does not require any additional process materials.

For some specifications, such as food cans, the three-piece can is supplied to the user with only one end seamed and in this case the end seaming is followed by palletisation. However, other three-piece cans such as paint cans, oblong cans and aerosols pass through a second seaming machine and a second end component is seamed prior to palletisation.

### 10.2.6 Two-piece drawn cans in steel and aluminium

The production process for two-piece cans is shown in Figure 10.7.

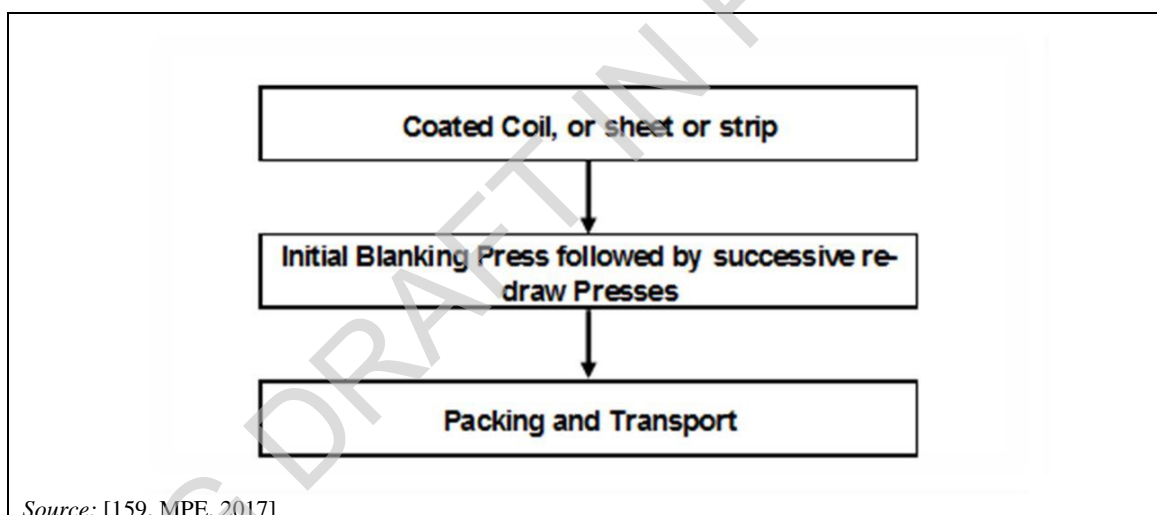


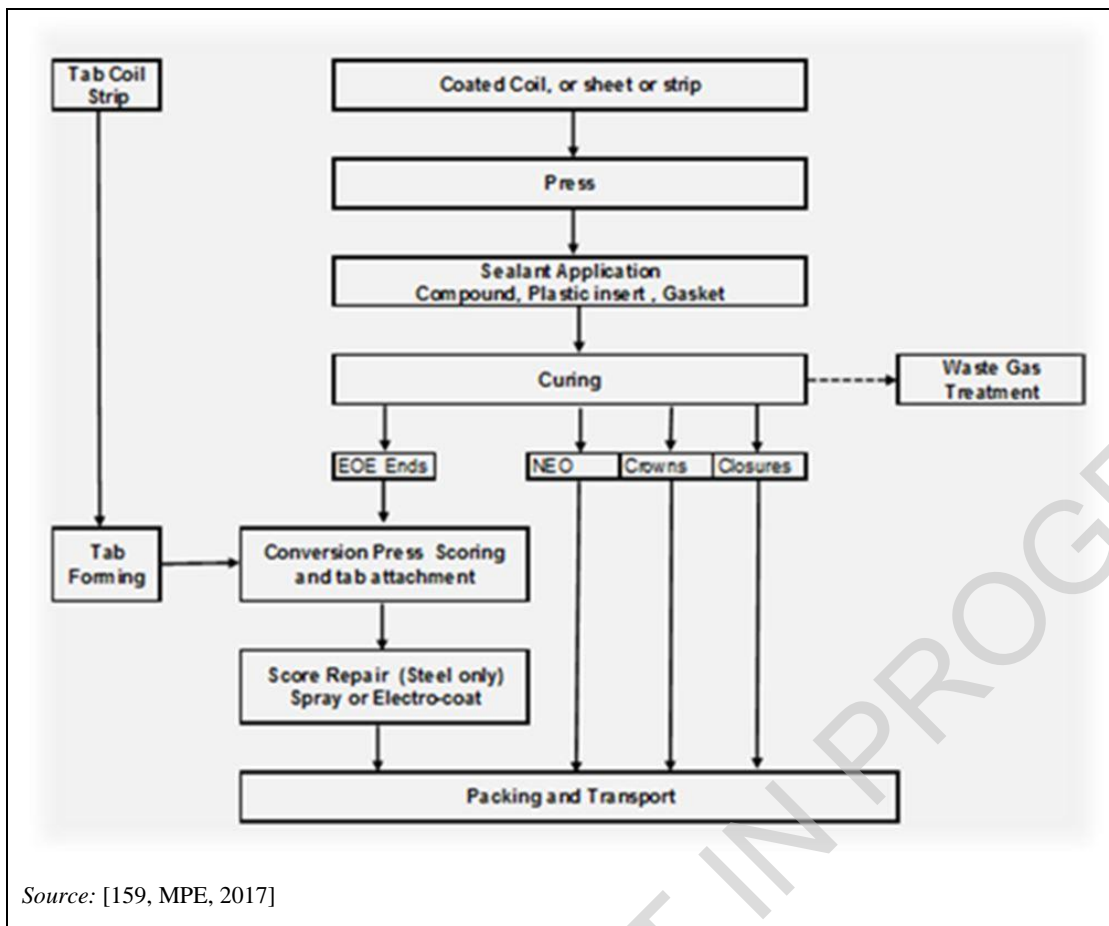
Figure 10.7: Production sequence of two-piece drawn cans

Two-piece drawn cans are produced from pre-coated coil, sheets or strips as described in Section 10.2.4. They can be produced in either rectangular shapes or into cylinders but they have constraints in the height of the container. They are commonly used with fish products.

In the manufacturing cycle, there are no VOCs used apart from in the flat sheet application process.

### 10.2.7 Ends, crowns and closures manufacture

The production process for ends, crowns and closures is shown in Figure 15.8.



**Figure 10.8: Production process for ends, caps and closures**

The manufacture is either from plain or pre-coated/decorated sheets or coil made from aluminium; or tinned or electrolytic chromium-coated steel (ECCS). The metal may be pre-lubricated prior to fabrication. The metal is fed to a stamping press where the initial round blank disc is formed. This disc is then repeatedly reformed depending on which type of component it will become: easy-open ends (EOE); sanitary or non-easy-open ends (NEOE); crowns or caps for bottles or closures for jars. These components are usually round, but there can be rectangular EOE and industrial components as well. There are also: cones and domes that are made for three-piece aerosol cans, other industrial components such as lever lids for paint and other specific closing mechanisms such as rectangular poring components for liquid products.

Multiple forming operations are carried out to complete the profile. The completed component shell then proceeds to a lining machine where a sealant (sometimes referred to as a lining compound) or gasket (sometimes referred to as a compound) is applied. Organic solvents may be contained in the sealant.

For easy-open ends, once the shell has had the compound applied, it proceeds on to a conversion press where the opening feature is created; the tab is fabricated and a final assembly is carried out to complete the end. For easy-open ends made from tinplate, the end score will be repaired with a spray lacquer or electrocoat material and an associated oven for curing. Some sealants and gaskets require passage through an oven for forced drying or curing. Once completed, the ends, crowns or closures are packed and palletised for despatch to customers.

### Flat sheet coating and priming

Flat sheet coating and printing operations follow four key processes:

- internal coating (exceptions are: aerosols, food containers for non-aggressive products, promotional packaging)
- external base coat or size, however, conventional print can be directly applied to tinplate
- printing
- varnish or top coating.

Curing of solvent based coatings and inks takes place in thermal ovens at rates of up to 8000 sheets per hour at temperatures of between 150 and 220 °C. Speeds and temperatures are dependent on sheet sizes, thickness and the coating specification.

Flat sheet coating and printing is the first separate and distinct operation necessary for the subsequent operations for the manufacture of three piece and drawn cans, ends or caps and closures. Figure shows the production process of flat metallic sheet.

**Figure: Production process for flat metallic sheet**  
[38, TWG, 2004]

The substrate materials used in the flat sheet printing and coating process are mainly tinplate, tin-free steel, blackplate or aluminium. The material is received either as stillages of pre-cut sheets or as coils which have to be processed on-site into the cut sheets.

Metal sheets may pass through the printing and coating lines several times as several coating and decorative applications and curing passes are sometimes required. Internal can coatings, as required by the product being packed, are generally applied first. This can be followed by application of an external base coat, a printed design and an external varnish in various combinations as required by the finished product.

On the coating lines, the material required for the design is pumped from a reservoir at the machine up to the application rollers. The subsequent excess material is collected and returned to the reservoir. The film weight is accurately set on the coating machine as required by quality standards and measurements.

On the printing lines, ink is spooned onto the application rollers by hand. Any subsequent excess material is collected and returned to the container on completion of the production run. The application of the ink to the sheet is measured to ensure the minimal required application rate is applied to achieve the desired depth of colour. The printing techniques commonly used are offset lithographic, dry offset and, in some cases, a waterless lithographic process may be employed.

Periodic cleaning of the coating and print rollers is required to remove the build up of coating and ink constituents. Excess coating is removed from the bottom roller whilst the machine is running by a scraper, to prevent contamination of the underside of the sheet.

At changeovers, more thorough cleaning of the coating and printing machines is carried out using various organic solvents, including reclaimed solvents, either manually or automatically. The waste organic solvent is often distilled and rebled either on-site or off-site.

The coated or printed sheet is then transferred to the thermal curing oven where it is heated to the required curing temperature. VOCs from the organic solvent used in the materials applied are collected from the oven exhaust and machine hoods with ducts and exhausted by fans to the air or sent to abatement equipment.

Following this, the cured sheet is cooled by drawing outside ambient air through fans and ducts and blowing it over the sheets. This reduces the materials sticking together and the stack of sheets is rebuilt on stillages for subsequent transfer to the next stage of the process.

Where UV curing inks and coatings are used, UV lamps are used. This does not release VOCs but creates a low level of ozone which is exhausted to the air.

### Three piece can manufacture

The production process for three piece cans is shown in Figure.

**Figure: Production process for three piece cans**  
[38, TWG, 2004]

Three piece can manufacture covers diverse products such as food cans, paint cans, oblongs, and aerosols. Tinplate sheets coated and/or decorated, as described earlier in Section **Error! Reference source not found.** under flat sheet coating and priming, are slit into individual body blanks. These body blanks are automatically fed into a welding machine that rolls the body blank into a tube and then welds it along its length to produce a straight sided welded cylinder. During slitting, the excess tinplate is trimmed off and subsequently recycled. The welding rolls and welding head are water cooled using chilled recirculating water. To ensure a quality weld, copper wire is fed over the internal and external weld rolls such that the entire length of each weld is produced using fresh copper wire as the electrodes. The used copper wire is chopped up, collected and returned to the manufacturers for recasting. An alternative means of joining the side seam is by mechanical clinching. In some cases, the circular cylinders can be reformed into other shapes, e.g. rectangular.

Immediately after welding, and while still on the welding machine, the internal surface and external surface of the weld may have a protective coating applied depending on the specification of the three piece can being manufactured. This protective coating is called a side stripe and may either be an organic solvent based, a water based or a powder coating, depending on the intended end use of the container. In the case of side stripe lacquers, these are applied using rollers or airless spray guns and any overspray is collected and ducted to the air. In the case of powder coatings, these are applied electrostatically and any overspray is collected and recycled.

Following welding/side stripe application, the cylinders pass through an oven to cure the applied side stripe. These ovens are generally either hot air or induction and apply a localised heat to the weld area of the cylinder. Emissions from the side striping oven are emitted directly to the air via exhaust stacks.

Following side stripe curing, some specifications of three piece cans (typically food cans) are then automatically fed into a beading machine so that strengthening beads can be fabricated into the body wall of the cylinder. This process is purely mechanical and requires no additional process materials. After beading or side stripe curing, depending on the can specification, the welded cylinders are automatically fed into either necking and flanging machines or just flanging machines so that both ends of the cylinder can be profiled ready to accept an end component. Again, necking and flanging are purely mechanical processes requiring no additional process materials.

The fabricated body is then automatically passed to an end seamer where an end component, previously manufactured, is fed and seamed onto one end of the fabricated cylinder. The seaming operation is also purely mechanical and does not require any additional process materials.

For some specifications, such as food cans, the three piece can is supplied to the user with only one end seamed and in this case, the end seaming is followed by palletisation. However, other three piece cans such as paint cans, oblong cans and aerosols pass through a second seaming machine and a second end component is seamed prior to palletisation.

### **End, cap and closure manufacture**

The production process for ends, caps and closures is shown in Figure.

**Figure: Production process for ends, caps and closures**  
[38, TWG, 2004]

The manufacture is either from a plain or pre coated/decorated sheet or coil in aluminium or packaging steel. The metal may be pre lubricated prior to fabrication. The metal is fed to a stamping press where the initial forming is carried out. Additional forming operations are carried out to complete the profile. The completed shell then proceeds to a lining machine where a sealant (sometimes referred to as lining compound) or gasket (sometimes referred to as compound) is applied. Organic solvents may be contained in the sealant.

Additionally, for easy opening ends, once the shell has had the compound applied, it proceeds on to a conversion press where the tab is fabricated and fitted and a final pressing is carried out to complete the end. For easy open ends made from tinplate, the end score will be repaired with a spray lacquer. Some sealants and gaskets require passage through an oven for forced drying or curing. Once completed, the ends, caps or closures are packed and palletised for despatch to customers.

### **Extruded aluminium tubes manufacture**

The production process of extruded aluminium tubes is shown in

**Figure: Production process of extruded aluminium tubes**  
[38, TWG, 2004]

Aluminium slug, which is 99.5 % pure aluminium, is lubricated and then converted in a series of high impact drawing operations into a tube with a single open end. The open end is trimmed to produce an even cylinder and the trim collected for recycling. Further separate metal from forming operations may inwardly dome the closed end for pressure resistance (aerosol), perforate it for later addition of a plastic screw thread and cap or further form it into a screw thread (the latter two for collapsible tubes).

The formed article is then cleaned in a continuous cleaner to remove residual lubricant and to prepare the surface for application of organic coatings. The chemicals used in the cleaning and etch process comprise caustic based anionic detergents. The contaminated waste water may be discharged partly or totally to a sewer with local consent and/or re-used to feed the caustic scrubber system described below as a means of fume abatement.

The cleaned cylinders are then transferred to a base coater whereby a metered coating of clear or pigmented base coat is applied by a roller with the cylinder rotating. The coating material is contained in a reservoir in which the pick up roller runs and excess material removed by the metering system is fed back into the reservoir. Typical base coats are organic solvent based but waterborne coatings may also be used. The coating station is extracted by fan and generally ducted to the air via high stacks. From the base coater, the coated cans pass automatically into a

drying/curing oven, the extract from which is collected and sent directly to the air via high stacks or to abatement equipment.

The cured base coat provides the key for the subsequent printed design, which is applied via a multicolour decorator using the dry offset process. Inks are hand spooned to the reservoir rolls and a precision system of rolls accurately meters each colour separately onto the applicator roll, which picks up the colours in register and transfers the complete image to the workpiece. A protective over varnish is applied as the final operation before the cylinder passes automatically into an oven for drying and curing. There is fume extraction at the decorator, which is ducted to the air having passed through a caustic scrubber and separate ducting of the oven exhaust to the air or abatement equipment.

For aerosol cans, the cylinder undergoes further reforming, with controlled application of a mineral lubricant, to 'neck in' and curl the open end to accept the valve assembly which will be fitted subsequently to filling.

### Drum manufacture

Steel drums are manufactured primarily for industrial use. The principle of manufacturing drums is similar to the three piece can manufacturing process. This is shown in

**Figure: Production process of drums**  
[38, TWG, 2004]

Generally the body, top and bottom are produced separately on cutting and forming lines, using plain steel. If required, the formed drum bodies and ends are separately coated with internal lacquer and cured. On the seaming machine, just before assembling of these components, the seaming compound is applied. As a last step, the drum is coated on the outside with external drum paint and the coating cured and dried simultaneously. Internal drum coatings are generally applied via rotation discs (for the body) or by hot airless spraying. The majority of internal coatings are solvent based because of the required chemical resistance against the filling goods and subsequently contain 45 to 65 % organic solvents. External drum paints are generally applied by hot airless spraying. External drum paints are mainly solvent based and contain around 50–55 % organic solvents. In specific cases, water based external drum paints are used, containing less than 10 % organic solvents. VOC process emissions are directed to the air via exhaust stacks or treated by abatement techniques first.



## 10.3 Current consumption and emission levels in the coating and printing of metal packaging

### 10.3.1 Submitted data

[155, TWG, 2016]

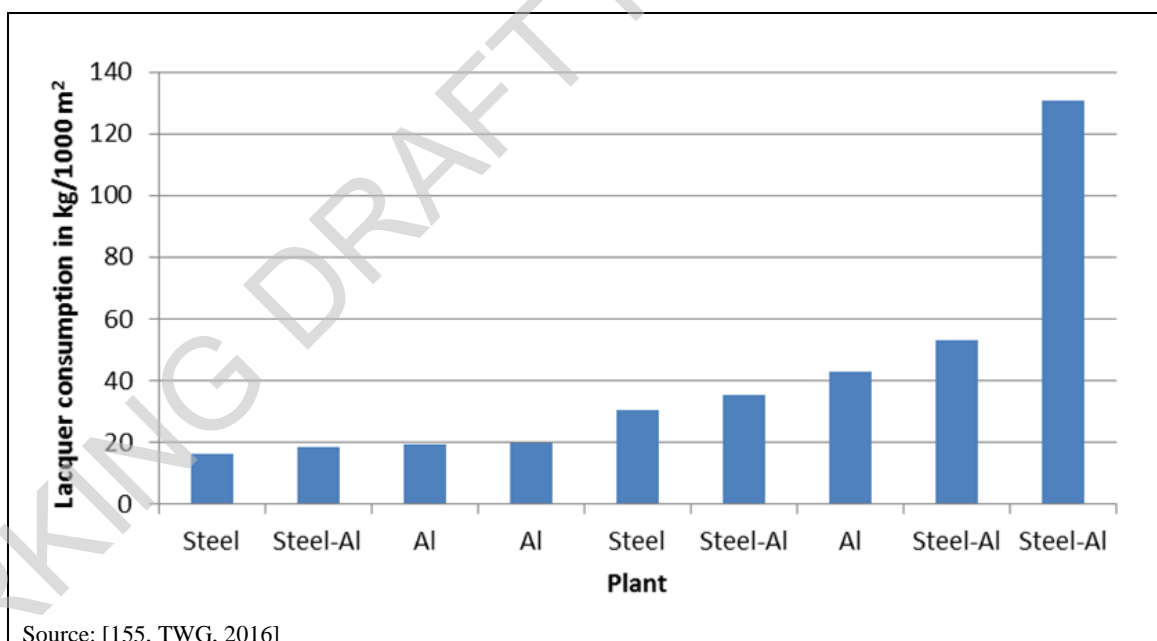
Data were submitted for 18 plants in total. Metal packaging is a sector where the application of the solvent reduction scheme is a common practice. For example, in the current data collection, 10 out of the 18 plants are applying the reduction scheme. There are different methodologies among the installations on how the provisions of the reduction scheme apply: in some cases installations do not apply any waste gas abatement technique but the compliance check is based on the reduction scheme methodology, while in other cases installations are under the reduction scheme methodology for their total VOC emissions but apply also VOC abatement techniques for a part of their channelled emissions. A third group of installations do not apply the reduction scheme and are regulated according to IED Annex VII provisions.

### 10.3.2 Consumption

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [155, TWG, 2016]

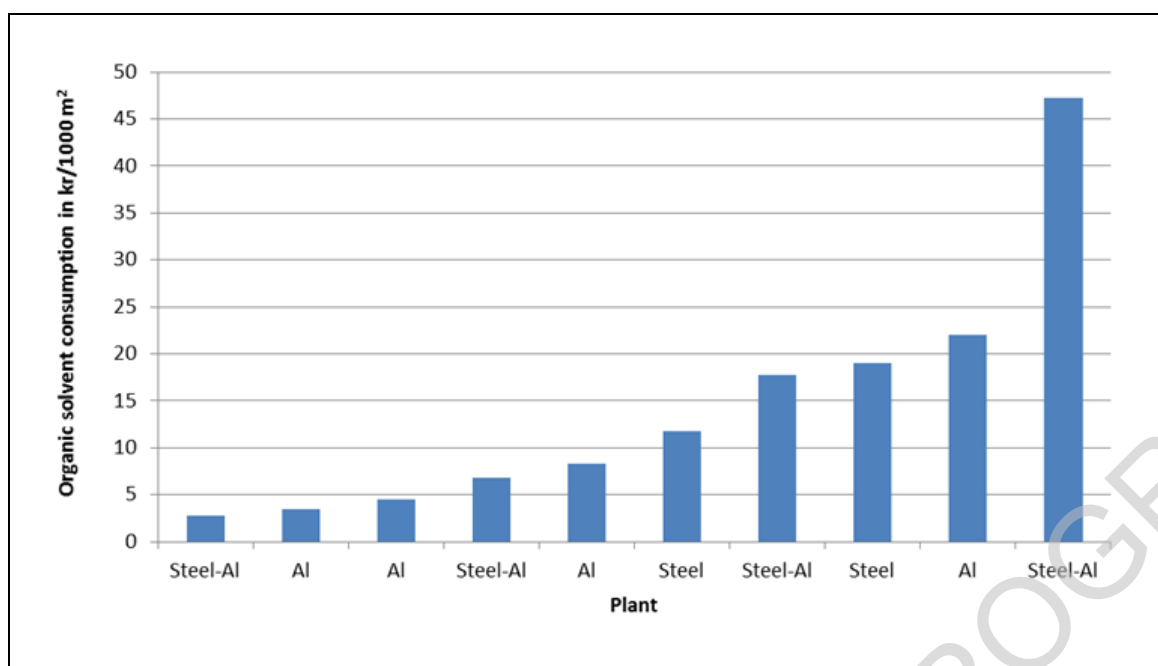
#### 10.3.2.1 Materials

Reported mass balance data show an average lacquer consumption that varies between 16 kg and 131 kg of lacquer per 1000 m<sup>2</sup> of product. The reported values are presented in Figure 10.9.



**Figure 10.9:** Reported values of specific lacquer consumption from metal packaging installations (kg of lacquer consumption per 1000 m<sup>2</sup> of product) - Average values for the period 2013–2015.

The average solvent consumption varies from 2.7 kg up to 47.2 kg of solvent per 1000 m<sup>2</sup> of product. The reported organic solvent consumption data are presented in Figure 10.10.



**Figure 10.10:** Reported values of organic solvent consumption from metal packaging installations (kg of solvent input per 1000 m<sup>2</sup> of product) - Average values for the period 2013–2015

Other consumption and emissions data for the various products and pre-products are given in the tables below.

**Table 10.2: Data for the coating and printing of beverage cans**

Plant reference	Plant A <sup>(1)</sup>	Plant B	Plant C
Substrate	Tinplate	Tinplate	Aluminium
Size and geometry of workpieces	33/50 cl	33/50 cl	15, 20, 25, 29.6, 33 and 35 cl
Frequency of colour changes	Approx. 500 decoration changes per year for the production of 33 cl cans and 1 100 for 50 cl cans	Approx. 400 decoration changes per year per production line	2 200 decoration changes in 1999
Annual capacity million of m <sup>2</sup> (base year 2000)	~ 120 tinplate	~ 100 tinplate	72.09 <sup>(2)</sup> aluminium
Solvent consumption (g of solvents/m <sup>2</sup> ) yearly amount (tonnes)	maximum 7.2 maximum 864	maximum 6.7 maximum 670	3.2 <sup>(2)</sup> about 250–300
Annual operation time (h)	6 500–8 400	6 500–8 400	8 300
Year of commissioning	1 978	1 984	1 968
NB: Food law requirements are applied to all three plants. <sup>(1)</sup> Plant A is a plant with a coating store house, applying dust filters, an adsorption installation and a regenerative thermal combustion unit for the treatment of waste gases. <sup>(2)</sup> Data from 1999. Source:[13, DFIU and IFARE, 2002]			

Table 10.3: Data for the coating and printing of flat sheet

Activities performed	Sheet coating and printing	Sheet coating and printing and three-piece can
Production of lacquered sheets (million)	22	10
Production of printed sheets (million)	68	21
Tonnage of sheets used (tonnes)	23 000	7 410
Energy (electricity) used (MWh)	3 600	2 000
Energy (gas) used (MWh)	6 600	1 600
Solvent consumption (tonnes)	210	105
Solvent emission (tonnes)	44	100
Water usage (tonnes)	2 030	2 610
<i>Source: [38, TWG, 2004]</i>		

Table 10.4: Data for three-piece can coating and printing

Activities performed	Three-piece cans
Production of cans (million)	434
Tonnage of tinplate used (tonnes)	25 300
Energy (electricity) used (MWh)	2 300
Energy (gas) used (MWh)	3 260
Solvent consumption (tonnes)	33
Solvent emission (tonnes)	30
Water usage (tonnes)	2 898
<i>Source: [38, TWG, 2004]</i>	

Table 10.5: Data for cap coating and printing

Activities performed	Caps
Sheets lacquered (million)	36
Sheets printed (million)	12
Production of caps (million)	920
Tonnage of tinplate used (tonnes)	9 126
Energy (electricity) used (MWh)	3 840
Energy (gas) used (MWh)	1 890
Solvent Consumption (tonnes)	300
Solvent emission (tonnes)	45
Water usage (tonnes)	1 053
<i>Source: [38, TWG, 2004]</i>	

Table 10.6: Mass balances for drum coating and printing

Activities performed	Metal drums
External paint/drum	250 g
Tonnage external paint/year	250 tonnes
Lacquer (internal coating)/drum	300 g
Calculation internal lacquer based on	50 % of all drums
VOC % in internal drum lacquer	65 %
% made with solvent-based (external paint)	90 %
% made with water-based (external paint)	10 %
VOC % in solvent-based	55 %
VOC % in water-based	10 %
Solvent consumption/year (external coating)	126 tonnes
Solvent consumption/year (internal coating)	98 tonnes
Total solvent consumption/year	224 tonnes
NB: Values refer to estimated mass balance per one million large drums. Source: [38, TWG, 2004]	

### Consumption

[13, DFIU and IFARE, 2002], [38, TWG, 2004]

#### Consumption of raw materials in the coating and printing of two-piece cans

The solvent consumption of two installations (Plants A and B) depends on the design and the filling (beverage) and is about 7.2 g per coated m<sup>2</sup> of tinplate. The capacities of these two plants were about 100–120 million m<sup>2</sup>, in the year 2000. 670 and 864 tonnes respectively of organic solvents from coatings and printing inks were processed.

The coating materials applied in the plants mentioned above are water-based. However, for an improved workability they contain 15–45 % organic solvents. Typically 10–12 g coating per m<sup>2</sup> tinplate is consumed. The varnish applied for coating the interior of the can normally contains 10–15 % organic solvents, and typically 19–22 g/m<sup>2</sup> varnish is consumed.

The can may be coated with a base coat to serve as a support for the ink layer. The base coat contains approximately 20–50 % organic solvents. The can is then printed. In other cases, this base is not used because the can is printed directly. The printing ink may contain between 18 % and 38 % of organic solvents and typically 0.5–0.7 g ink per m<sup>2</sup> tinplate is consumed. The can may optionally then be coated with a thin layer of overvarnish for the protection of the print. The overvarnish contains approximately 25–35 % organic solvents.

The consumption data for the processing of aluminium in one plant are shown in Table 10.7.

Table 10.7: Consumption of materials in one plant

Process step	Material	Consumption (t/yr)	Comments
Base coating	Lacquer	127	12.5 wt-% solvents
Printing	Printing inks	58	15 wt-% solvents
Overvarnish	Overvarnish	257	16 wt-% solvents
Bottom varnish (roller application)	Bottom rimcoat	19	33.5 wt-% solvents
Inside coating	Lacquer	1 050	15 wt-% solvents
Complete painting process	Cleaning agents, solvents	26	
Total process	Water	135 000	
Cleaning process		172	Sulphuric acid, tensides
Cleaning process		55.4	Nitric acid, phosphoric acid, hydrofluoric acid
Surface pretreatment		53	Hydrofluoric acid
Surface pretreatment		24	Improvement of mobility
Adsorption wheel	Activated charcoal	2	
Waste water treatment	Lime	82.3	
	Anti-foaming agent	2.1	
	Flocculant	2.54	
	Breakdown agent	12.1	Ferroline
	Breakdown agent	14.4	
	Caustic soda	35.1	
	Hydrochloric acid	34.5	
	Sulphuric acid	5.78	

*Source:* [13, DFIU and IFARE, 2002], [38, TWG, 2004]

#### Consumption of raw materials in the coating of drums

On average for 217-litre drums, one drum line produces around 400 drums per hour (the maximum output is 600 drums per hour). All drums are externally painted. The amount of external paint used is around 250 grams per drum and the solvent consumption will be around 50–55 kg/h if solvent-based coatings are used. Some installations have several drum lines. The internal coating (50 % of the drums) could be done simultaneously on a separate coating line (spray booth + oven) dedicated either for bodies or for ends and the additional consumption of solvent is 80 kg/h. For reasons of chemical durability, phenolic coatings might be used, which have some phenol content.

[78, TWG, 2005]

#### Consumption of raw materials in the coating and printing of flat sheet

For the coating operation, the solvent consumption varies to a large extent depending on the end use of the can and the substrate metal used. The applied solids may range from 4 g/m<sup>2</sup> to 6 g/m<sup>2</sup> exterior gold coating for a standard can, and up to 25 g/m<sup>2</sup> for the interior gold coating for a can designed for aggressive products. The typical range of solvent content in the coatings used ranges from 45 % to 70 %. For certain specific applications, water-based coatings are being used which range from 10 % to 25 % solvent content. The printing usage of solvents is about 10 % of the solvent consumption for the coating operation.

Table 10.8 shows data on consumption of raw materials in the coating and printing of flat sheet.

**Table 10.8: Consumption of raw materials in the coating and printing of flat sheet**

Application		Typical film weight (g/m <sup>2</sup> )	Typical solids content (%)
Three-piece bodies	Interior	5–40	30–35
	Exterior gold	4–6	30–40
	Exterior size	2–3	25–35
	Exterior white	12–16	50–60
	Exterior varnish	5–7	35–45
	Exterior varnish (UV)	5–7	100
End components	Interior	4–14	30–55
	Exterior gold	4–7	30–40
	Exterior size	2–3	25–35
	Exterior white	12–16	50–60
	Exterior varnish	5–7	35–45
	Exterior varnish (UV)	5–7	100
Caps and closure	Interior system	10–20	40–50
	Exterior size	2–3	30–40
	Exterior white	10–15	50–60
	Exterior varnish	2–4	35–45

*Source: 38, TWG, 2004*

### Consumption of raw materials in the coating and printing of three-piece cans

The can's protective side stripe coating can be either a water-based material, solvent-based or powder. The selection of the side stripe coating is dependent upon the type of can, its end use and the film weight necessary for product resistance. A critical feature of the cured side stripe coating is the ability to withstand metal deformation at the beading and flanging stages.

The range of the film weight is 5 g/m<sup>2</sup> to 25 g/m<sup>2</sup> for liquid side stripes. This equates to potential VOC levels of between 5 g/m<sup>2</sup> and 100 g/m<sup>2</sup> of side stripe (that is 8–160 mg VOCs per typical 0.5 g can).

For powder side stripes, the range of the film weight is 70 g/m<sup>2</sup> to 140 g/m<sup>2</sup>. There are no VOC emissions associated with powder side stripe application.

Currently there is no one side stripe standard technology or material capable of meeting all can-making specifications.

Table 10.9 shows data on consumption of raw materials in the coating and printing of three-piece cans.

**Table 10.9: Consumption of raw materials in the coating and printing of three-piece cans**

Application		Typical film weight (g/m <sup>2</sup> )	Typical solids content (%)
Side stripe	Liquid	5–20	15–25
	Powder	70–140	100

*Source: [38, TWG, 2004]*

### Consumption of raw materials in the coating and printing of ends, caps and closures

In addition to preventing leakages, sealants and gaskets must also provide essential biological safety, especially in the case of food and beverage cans, ends and closures.

Sealant and gasket compound consumption is measured in volume as opposed to weight per area unit. When a repair spray is required, a typical number would be 95 g per 1000 ends (EOE) for a diameter of 73 mm. All repair sprays are solvent-based only. Typical sealant volumes are shown in Table 10.10 below.

**Table 10.10: Consumption of raw materials in the coating and printing of ends, caps and closures**

Diameter (mm)	Food can ends	Drink can ends	General line can ends	Aerosol can tops	Aerosol can bases
48				35–55	
50		22 – 33			28 – 48
52	30 – 45	25 – 35		40 – 60	
54					30 – 50
57		30 – 40			
60				40 – 70	
63					35 – 60
65				45 – 75	35 – 60
70			40 – 65		
73	30 – 50				
83	40 – 60				
99			70 – 100		
153	80 – 110		150 – 225		
165			165 – 245		
Compound volume (mm <sup>3</sup> ) for different can/end diameters and applications Source: [38, TWG, 2004]					

### 10.3.2.2 Water

No data submitted.

Reported values of specific water consumption for the manufacturing of two-piece cans vary from 90 l up to 110 l per 1000 cans.

The main reported techniques for the minimisation of water consumption are related to:

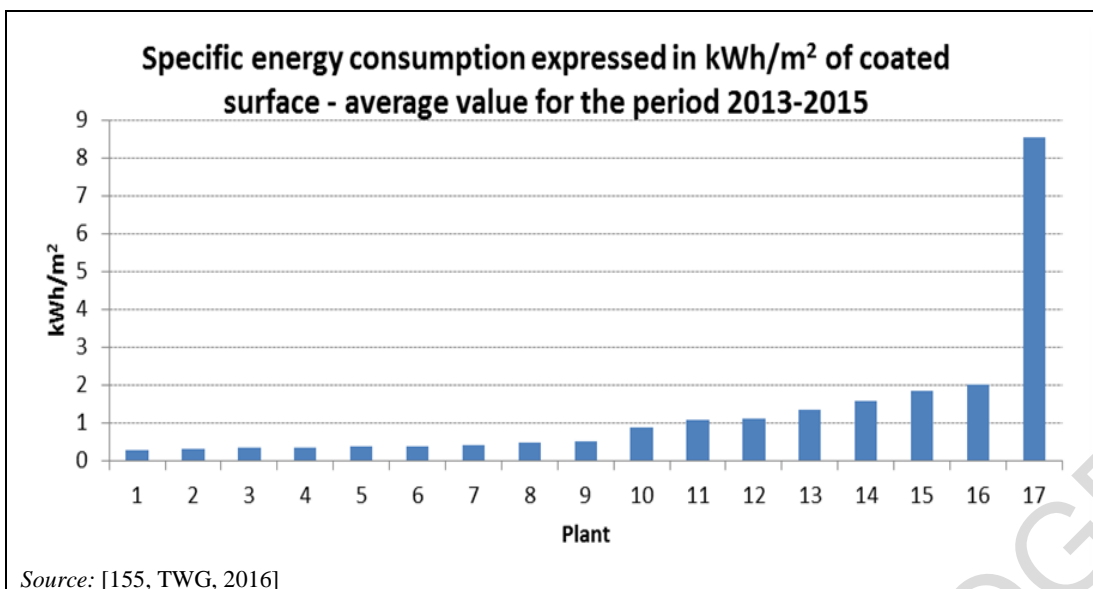
- control of water usage;
- reverse cascade rinsing;
- use of ion exchange;
- membrane filtration.

### 10.3.2.3 Energy

Natural gas and electricity are the main energy inputs in metal packaging installations. A significant part of the total energy consumption is dedicated to the waste gas extraction and treatment.

It is estimated that between 30 % and 50 % of the total electricity consumption is dedicated to gas extraction and treatment, while most of the gas consumption (up to 80%) is used for thermal waste gas treatment.

The reported values of the specific energy consumption are presented in Figure 10.11.



**Figure 10.11: Specific energy consumption values (kWh/m<sup>2</sup> of coated surface) - Average values for the period 2013–2015**

All but one installation reported specific energy consumption values are below 2 kWh/m<sup>2</sup> and are mainly related to plants where energy is recovered from the thermal treatment of waste gases. At the plant with excess specific energy consumption, thermal treatment of the VOC content in off-gases is carried out without energy recovery. No significant differences in specific energy consumption according to the product type were identified.

The main reported techniques related to energy saving are:

- air extraction and energy recovery from the drying processes; a reported figure shows annual savings of the order of EUR 110 000;
- exhaust air heat exchanger in ventilation systems;;
- air extraction and energy recovery from drying processes
- air extraction and energy recovery from the cooling zone;
- pressurised air: efficiency/pressure level: use of lower pressure level and substitution of pneumatic systems by electric control systems;
- reduced air ventilation at idle operation or maintenance;
- thermal insulation of tanks and vats with heated liquids;
- heat recovery from waste gas abatement;
- central waste gas treatment with variable frequency drives;
- oxidiser heat saving during shutdown periods;
- optimising of curing cycles and lacquer weight.

#### **Consumption of energy in the coating and printing of two piece cans**

The energy consumption of example plants A and B in the year 1999 – 2000 is shown in Table.



	<b>Plant A (MWh)</b>	<b>Plant B (MWh)</b>
<b>Natural gas</b>	67000	60000
<b>Electricity</b>	43000	55000
<b>Regenerated energy</b>	4000	
Note: Plant A and B are described in Section 10.3.2.1		

**Table: Energy use and recovery in two installations**

[13, DFIU and IFARE, 2002], [38, TWG, 2004]

### 10.3.3 Emissions

[155, TWG, 2016]

The abbreviations used in the presentation of emission data for metal packaging installations are presented in Table 10.11.

**Table 10.11: Abbreviations used in this chapter**

<b>Abbreviation</b>	<b>Meaning</b>
2-p d c	Two-piece drawn cans
2-p w-i cans	Two-piece wall-ironed cans
3-p aerosol can	Three-piece aerosol cans
3-p food can	Three-piece food contact can
3-p ind. c	Three-piece industrial containers
vs	Varnished sheets
bc	Beverage cans
e/c/c	Ends/caps/closures
RS	The installation is implementing a solvent reduction scheme according to IED Annex VII, Part 5 provisions

#### 10.3.3.1 VOC emissions [to air]

[13, DFIU and IFARE, 2002], [38, TWG, 2004]

Table shows a summary of the VOC emissions reported:

	<sup>1</sup> Emission level at application (g/m <sup>3</sup> )	
	<b>Solvent-based</b>	<b>Water-based</b>
<b>Food contact</b>		
• DWI drinks	6.7–10.5	3.2–4.5
• sheet for ends, cans and components	4–93	1–30
• drums	90–100	
<b>Non food contact</b>		
• sheet for ends, cans and components	4–93	1–30
• drums	60–70	11–20
<b>Print varnish</b>		
• sheet for ends, cans and components <sup>2</sup>	2.5–13	1–6
Notes:		
<sup>1</sup> Values also include fugitive emissions		
<sup>2</sup> UV ink and varnish applications are limited to non-food and special applications and can achieve lower levels than 1		
No data have been reported for aluminium tubes		

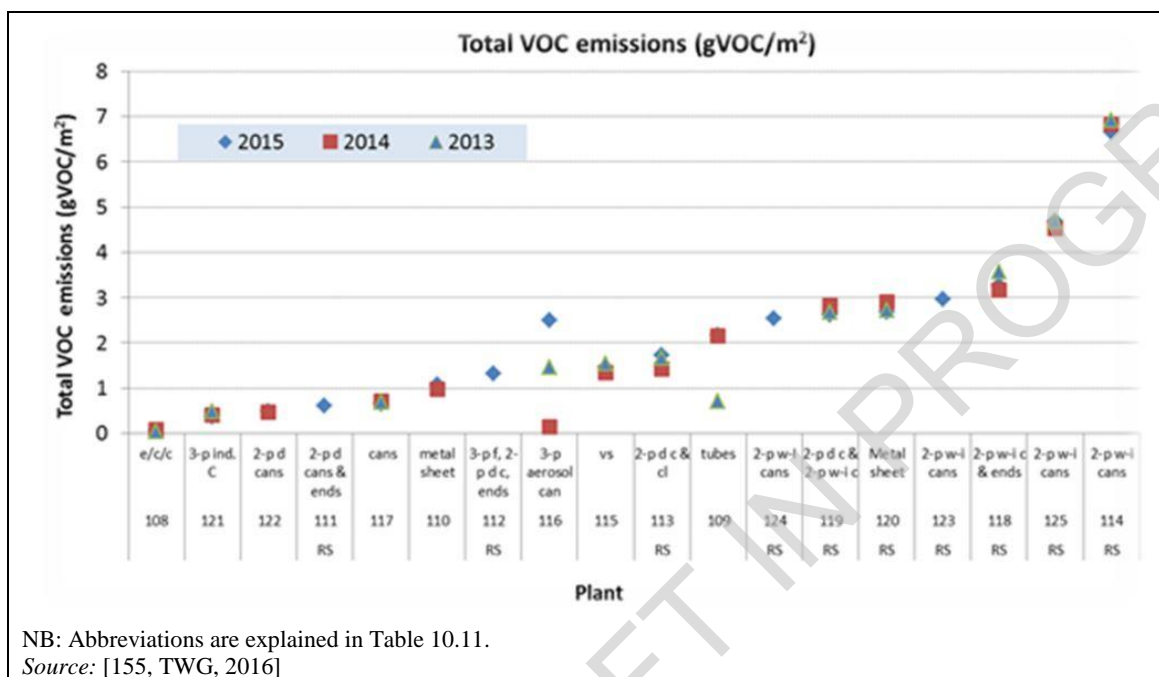
**Table: VOC emissions levels reported in different coating and printing of metal packaging**

[38, TWG, 2004] [74, SEFEL, 2005]

10.3.3.1.1 Total VOC emissions

Figure 10.12 shows an overview of reported total VOC emission values expressed as g VOCs per m<sup>2</sup> of coated surface for installations producing various products types (mainly two-piece drawn cans, two-piece wall-ironed cans, caps ends and closures).

It is worth noting that a significant share of installations in this sector apply the solvent reduction scheme (RS) according to IED Annex VII, Part 5 provisions.



NB: Abbreviations are explained in Table 10.11.  
Source: [155, TWG, 2016]

Figure 10.12: Reported total VOC emission values (g VOCs emitted per m<sup>2</sup> of coated surface) for various types of metal packaging production

Data reported from the relevant industry sector on total VOC emission values according to the product type and the abatement technique implemented are presented in Table 10.12.

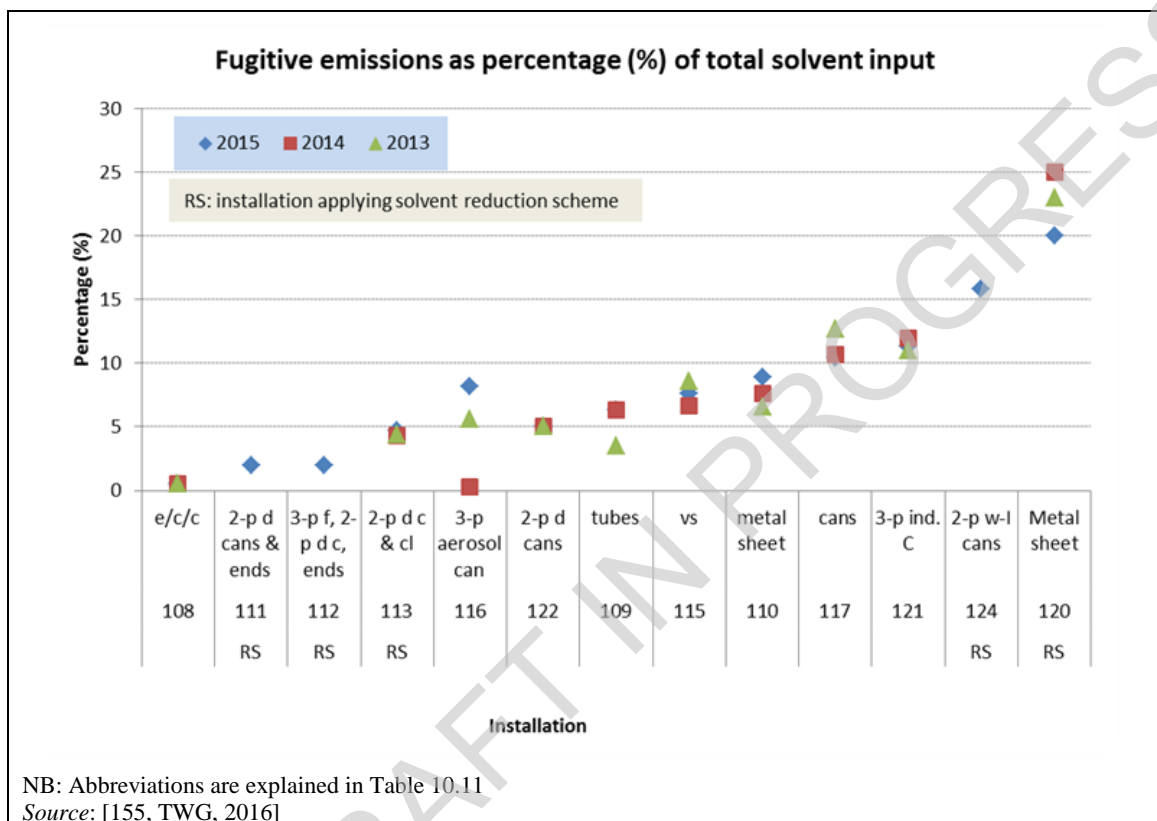
Table 10.12: Total VOC emission values (g VOCs per m<sup>2</sup> of coated area) reported by industry

Specific emission (g VOCs / coated area in m <sup>2</sup> )	Substrate	Production	Incineration
< 1	Steel / Aluminium	<ul style="list-style-type: none"> <li>DWI</li> <li>Flat sheet coating and printing</li> </ul>	Complete treatment of captured VOCs
1–3	Steel	<ul style="list-style-type: none"> <li>DWI</li> <li>Manufacturing comprising more than one technology (Flat sheet coating and printing, three-piece can making, end making, DWI)</li> </ul>	Partial treatment of captured VOCs
2–4	Aluminium	<ul style="list-style-type: none"> <li>DWI</li> <li>Monobloc</li> </ul>	Reduction scheme
5–10*	Steel	<ul style="list-style-type: none"> <li>DWI</li> <li>Flat sheet coating and printing</li> </ul>	Reduction scheme

\* Specific emissions may be higher in sectors where special requirements on lacquer composition are required  
Source: [172, MPE, 2017]

### 10.3.3.1.2 Fugitive VOC emissions

Waste gases from printing machines, coating applications and dryer units are usually extracted and treated in regenerative thermal oxidation systems. In addition, the application of techniques related to solvent storage and handling and the prevention of unplanned releases result in fugitive emissions lower than 15 % of the total solvent input in most cases (see Figure 10.13).



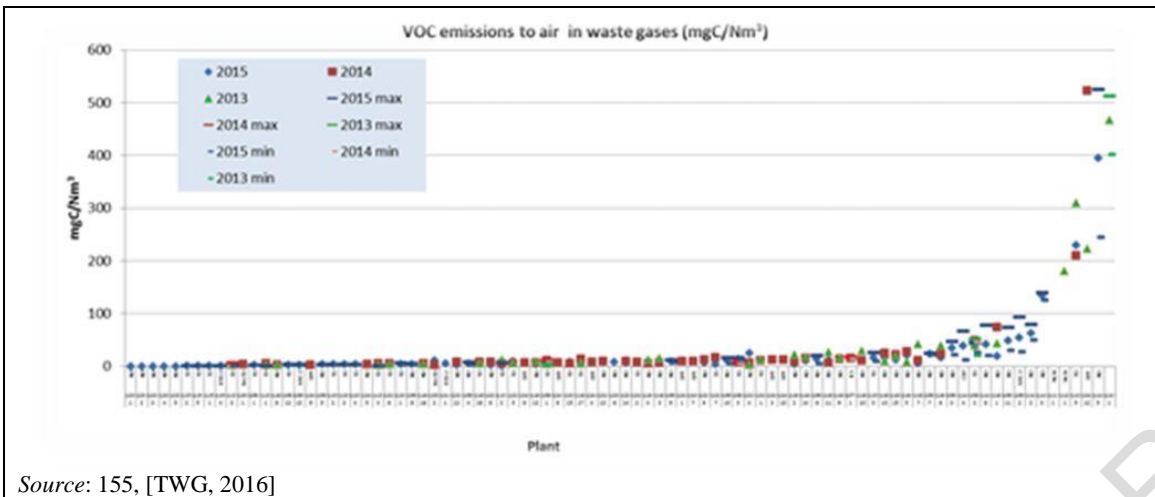
**Figure 10.13: Reported values of fugitive emissions expressed as a percentage of the total solvent input**

The main reported techniques for the limitation of fugitive VOC emissions are:

- safe storage of solvents and measures to prevent unplanned releases;
- handling and use of hazardous materials;
- air extraction from drying processes;
- air extraction from the cooling zone with treatment;
- enclosed application zones with air extraction.

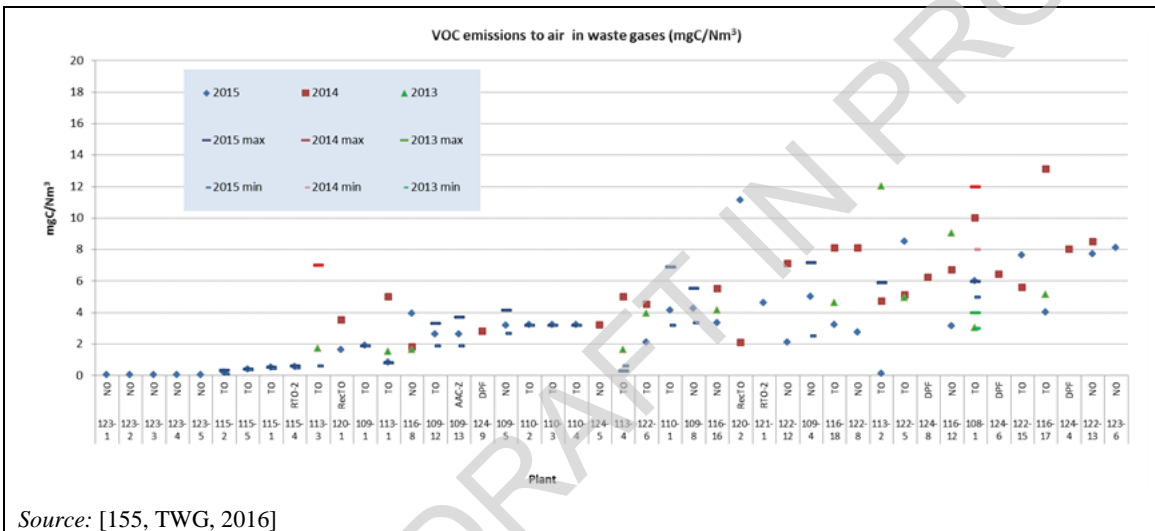
### 10.3.3.1.3 VOC emissions to air in waste gases

In general, VOC emission values in waste gases below 20 mg/Nm<sup>3</sup> are achieved, depending on the origin of the emission (the process), the applied abatement technique and the inlet (off-gas) concentration. The full set of reported figures is presented in Figure 10.14. In Figure 10.15 and Figure 10.16 the same data set is presented divided into two parts in order to allow a better presentation of submitted data.



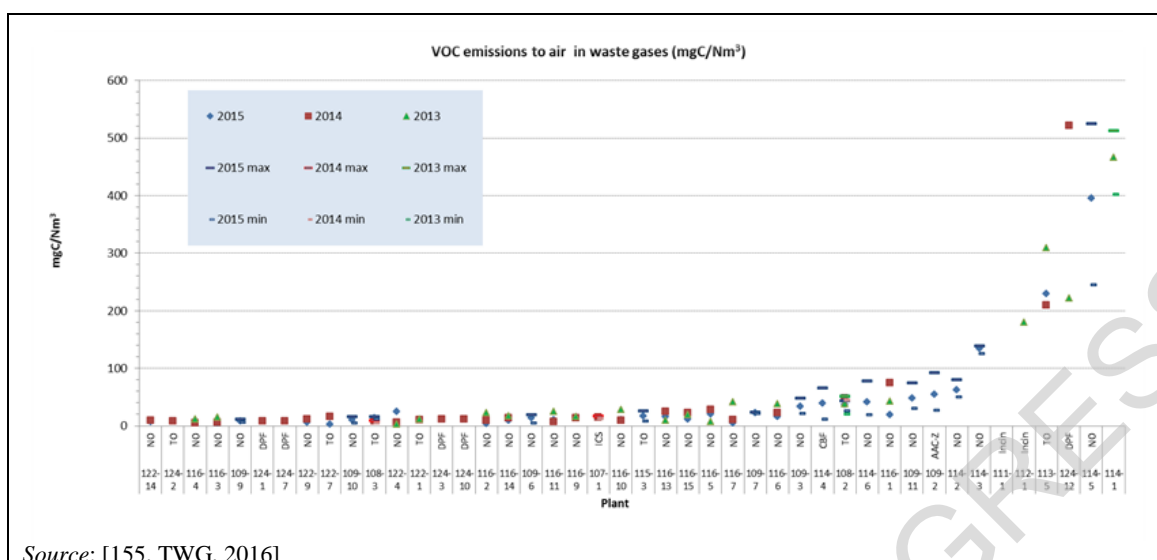
Source: 155, [TWG, 2016]

Figure 10.14: Full set of reported values of VOC emissions to air in waste gases (mg/Nm<sup>3</sup>) for the reference period 2013–2015



Source: [155, TWG, 2016]

Figure 10.15: First half of the sorted set of reported values of VOC emissions to air in waste gases (mg/Nm<sup>3</sup>) for the reference period 2013–2015



Source: [155, TWG, 2016]

**Figure 10.16:** Second half of the sorted set of reported values of VOC emissions to air in waste gases ( $\text{mg}/\text{Nm}^3$ ) for the reference period 2013–2015

Most of reported data refer to a monitoring frequency of once a year with a few cases of monitoring every six months and one case with a monitoring frequency of once every five years.

The basic statistical parameters of the reported data are presented in Table 10.13.

**Table 10.13:** Statistical parameters of reported values for VOC emissions to air in waste gases

Year / parameter		No of values	Average	75 <sup>th</sup> percentile	Median	25 <sup>th</sup> percentile
2015	Values	71	20.9	14.5	6.0	2.9
	Max.	34	38.8	39.4	6.5	3.2
	Min.	34	19.2	17.9	3.3	1.9
2014	Average	50	25.7	12.8	8.4	5.6
	Max.	5	19.4	-	-	-
	Min.	4	17.8	-	-	-
2013	Average	34	46.4	27.5	11.9	3.95
	Max.	3	-	-	-	-
	Min.	3	-	-	-	-

Source: 155, TWG, 2016

### 10.3.3.2 Dust emissions to air in waste gases

The reported values of dust emissions to air in waste gases are presented in Figure 10.17. The reported monitoring frequency varies from once a year up to once every three years.

The basic statistical parameters of reported dust emission data are presented in Table 10.14.

Table 10.14: Statistical parameters of reported values for dust emissions to air in waste gases from metal packaging installations

Year / parameter	No of values	Average	75 <sup>th</sup> percentile	Median	25 <sup>th</sup> percentile	
2015	Values	28	0.95	0.79	0.45	0.18
	Max.	8	0.35	0.53	0.25	0
	Min.	8	0.11	0.2	0.05	0
2014	Average	37	4.71	5.8	1.6	0.7
	Max.	1	ND	ND	ND	ND
	Min.	0	ND	ND	ND	ND
2013	Average	24	1.84	2.25	1	0.75
	Max.	0	ND	ND	ND	ND
	Min.	0	ND	ND	ND	ND

NB: ND = No data.  
Source: 155, TWG, 2016

Most of the reported data refer to an annual monitoring frequency while in some cases a monitoring frequency of once every two years was reported.

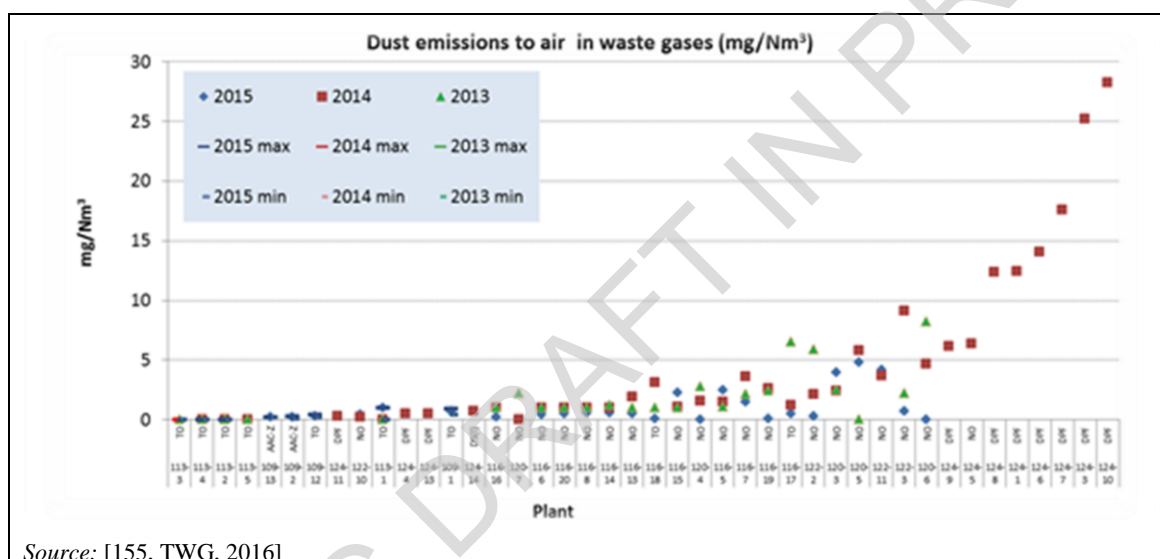


Figure 10.17: Reported values of dust emission to air in waste gases for metal packaging plants for the reference period 2013–2015 - Periodic monitoring

As shown in Figure 10.17, according to the submitted data, low dust emission values are not only associated with the application of dust-specific end-of-pipe abatement techniques but also with thermal treatment techniques, which focus on VOC emission reduction. However, there are low dust emissions where no abatement technique is applied (indicated with NO on the x axis). There is no information whether this is due to in-process techniques or the emissions are from a part of the process which does not produce dust. The dust emission values above 5 mg/Nm<sup>3</sup> all refer to various emission points of the same installation.

### 10.3.3.3 NO<sub>x</sub> and CO emissions to air

The reported measured concentration values of nitrogen oxides (NO<sub>x</sub>) and carbon monoxide (CO) emissions to air are presented in Figure 10.18. The reported monitoring frequency varies from once a year up to once every three years.

The basic statistical parameters of the reported values for NO<sub>x</sub> and CO emissions to air in waste gases are presented in Table 10.15.

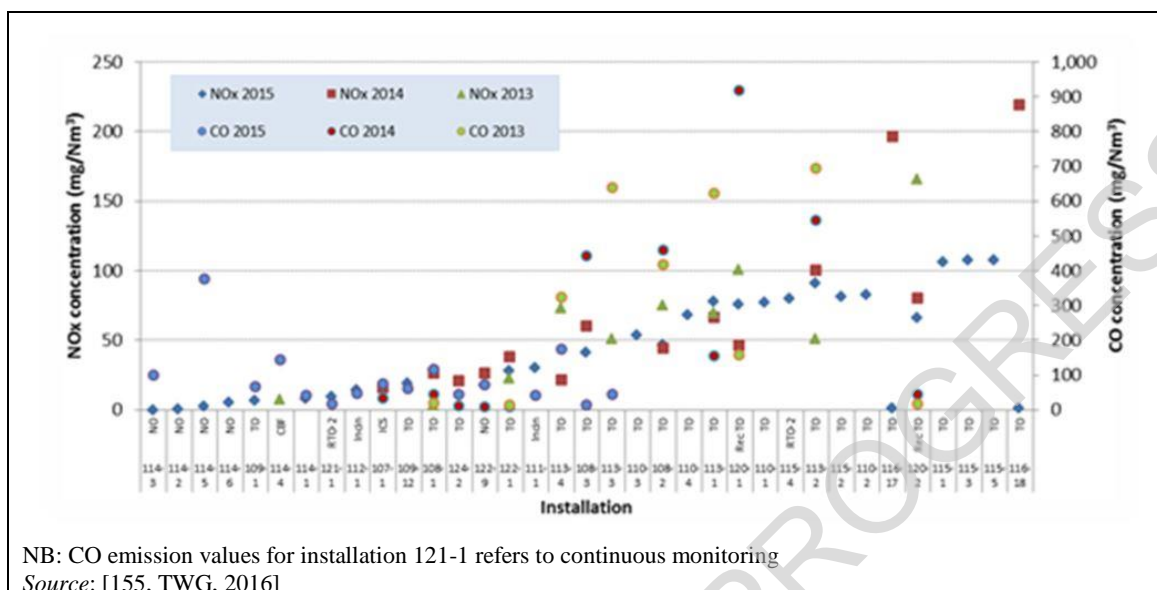


Figure 10.18: Reported values of NO<sub>x</sub> and CO concentration for the reference period 2013–2015 - Periodic monitoring

Table 10.15: Statistical parameters of reported values of NO<sub>x</sub> and CO emissions

Year / parameter	No of values		Average		75 <sup>th</sup> percentile		Median		25 <sup>th</sup> percentile	
	NO <sub>x</sub>	CO	NO <sub>x</sub>	CO	NO <sub>x</sub>	CO	NO <sub>x</sub>	CO	NO <sub>x</sub>	CO
2015	30	28	45	71	78	95	36	48	8	37
2014	14	12	69	222	76	447	45	44	26	9
2013	10	9	62	322	75	621	61	323	30	19

#### Emissions to air from the coating and printing of two piece cans

Due to extraction and treatment via regenerative, thermal combustion of waste gases from printing machines, coating applications and drier units, the amount of VOC emissions is relatively low. The efficiency of the waste gas treatment is more than 99 %; however this depends on inlet concentration. The mass flow of total C in the clean gas after the regenerative incineration process is in the range of 0.6–1.2 kg/h. Clean gas concentrations of <20 mg C<sub>total</sub>/Nm<sup>3</sup> are achieved.

**Error! Reference source not found.** shows emission data from plant A applying a regenerative incinerator with a capacity of treating a gas volume flow of 76000 Nm<sup>3</sup>/h for two production lines, and applying an adsorption wheel treating a gas volume flow of 90000 Nm<sup>3</sup>/h also for two production lines:

Parameter	Mass flow (kg/h)	Mass flow (kg/yr)	Comments
VOC	No data	No data	
C Total	0.61	5075	After incineration
	1.2	10080	After adsorption wheel
Dust	0.00015	1.27	After incineration
CO	1.37	11400	After incineration
NO <sub>x</sub>	1.52	12600	After incineration

Table : Emission values of clean gas after waste gas treatment from plant A [13, DFIU and IFARE, 2002]

**Error! Reference source not found.** shows emission data from plant B applying a regenerative incinerator with a capacity of treating a gas volume flow of 71240 Nm<sup>3</sup>/h for three production lines, and applying a bioscrubber treating a gas volume flow of 31820 Nm<sup>3</sup>/h for two production lines.

Parameter	Mass flow (kg/h)	Mass flow (kg/yr)	Comments
VOC	No data	No data	
Total-C	1.19	6764	After incineration
	0.3	252	After bioscrubber
Dust	0.03	202	After incineration
CO	0.69	3929	After incineration
NO <sub>x</sub>	1.71	9721	After incineration

**Table : Emission values of clean gas after waste gas treatment from plant B**  
[13, DFIU and IFARE, 2002]

**Error! Reference source not found.** shows emission data from plant C applying a regenerative incinerator with a capacity of treating a gas volume flow of 35000 Nm<sup>3</sup>/h, and applying an adsorption wheel treating a gas volume flow of also 35000 Nm<sup>3</sup>/h. The solvent laden air from the ground coat and topcoat applications is led through the adsorption wheel, achieving an efficiency of 54.4 % for butoxyethanol and 16.7 % for dibutylaminoethanol. The outlet gas from the adsorber is subsequently routed to the incinerator. Air extracted from the driers is only routed to the combustion unit, achieving a removal efficiency of 99.9 %.

Parameter	Mass flow (kg/h)	Mass flow (kg/yr)	Concentration (mg/m <sup>3</sup> )	Comments
Total-C	1.75	14525	50	After adsorption
	<0.07	581	<2	After incineration
Dust				
CO	2.55	21206	73	After incineration
CO <sub>2</sub>		8290		Incinerator and driers
NO <sub>x</sub>	2.80	23240	80	After incineration

**Table : Emission values of clean gas after waste gas treatment from plant C**  
[13, DFIU and IFARE, 2002]

VOCs are mainly emitted as fugitive emissions from, e.g. transport processes, conveyor systems or at the withdrawal of driers. From plants A, B and C, about 31–47 t VOC per year were emitted as fugitive emissions. The estimated fugitive emissions from plant C are 34 t/yr, which is 15 % of the solvent input.

The emission of VOC from varnishes and from cleaning (before treatment) is reported to be in the range of 10–12 g/m<sup>2</sup> tinplate [10, Spain, 2000].

#### Emissions to air from drum coating and printing

**Error! Reference source not found.** shows emissions data from the coating and printing of drums:

Waste-gas abatement (WGT)	30 %
VOC eliminated by WGT	67 tonnes
VOC emissions to air	143 tonnes/year
Note: Typical estimated emissions per million large drums	

**Table : Emissions to air from the coating and printing of drums**  
[38, TWG, 2004]



### 10.3.3.4 Emissions to water

[155, TWG, 2016]

Data for emissions in waste water were submitted for only three plants. Two of them discharge to a sewage system with downstream waste water treatment and the third discharges directly to the receiving water body after mixing with other treated waste water streams from other activities.

The reported ranges of pollutant concentrations are as follows:

- COD: 82–596 mg/l;
- TSS: 5–785 mg/l;
- Zn: 0.02–0.091 mg/l;
- Crtotal: 0.01075–< 0.046 mg/l;
- F-: 4–23 mg/l;
- AOX: 0.31–0.51 mg/l;
- Al: 0.75 mg/l.

#### **Waste water in the coating and printing of two piece cans**

Waste water is generated from the pretreatment processes. The concentrations of tin result from the cleaning of the deep drawn cans made of tinned tinplate. After precipitation and flocculation the concentrations of tin are 4 and <2 mg/l for plant A and B respectively.

AOX values after treatment are 0.5 and <1 mg/l for plant A and B respectively. Concentration of hydrocarbons after treatment were, for both plants, <20 mg/l. The treated waste water of plant C has a COD concentration of 350 mg/l and for AOX 0.5 mg/l.

### 10.3.3.5 Waste generation

[13, DFIU and IFARE, 2002], [155, TWG 2016]

#### **Waste from coating and printing of two-piece cans**

The main reported waste streams are related to:

- inks, lacquers;
- waste related to cleaning activities such as: absorbents, filter materials, cleaning clothing;
- paint or varnish sludges;
- sludges from the waste water treatment;
- empty containers and other contaminated packaging;
- oil residues and oil separator waste.

Reported values for the main waste categories are presented in Table 10.16.

**Table 10.16: Ranges of reported values of waste generation for the main waste streams for two-piece can coating installations**

Waste type	Waste quantity produced (g of waste per m <sup>2</sup> of coated surface)
Paint and varnish sludges	0.16
Lacquers and grease	0.22
Inks, paints and varnishes	0.30
Absorbents, filter materials, cleaning clothing	0.21–5.1

Other solvents and solvent mixtures	0.5–1.8
Empty containers and other contaminated packaging	5.4

Source: 155, TWG, 2016

Significant wastes from the production process are shown in **Error! Reference source not found.** The amount of waste is expressed in tonnes per year and as a relative value to each square metre of tin or aluminium processed.

Waste	Plant A		Plant B		Plant C	
	(t/yr)	(g/m <sup>2</sup> )	(t/yr)	(g/m <sup>2</sup> )	(t/yr)	(g/m <sup>2</sup> )
Coating sludge from the cleaning of installations	2.95	0.025				
Solvents and solvent mixtures	42.15	0.351			8	0.11
Organic solvents, cleaning agent and alkaline solutions	56.79	0.473				
Oil-contaminated filters, cleaning wipes and protective clothing	61.66	0.514	43	0.43	5.2	0.02
Coating sludge			87.00	0.87	32	0.40
Varnish filters			6	0.06		
Packaging with hazardous contaminations			8	0.08		
Sludge from cleaning tanks					11	0.15
Oil residues					12.4	0.17
Lime sludge					316	4.0
Mixed industrial waste					53	
Aluminium scrap					3.63	

Table : Wastes arising from coating and printing of metal packaging [13, DFIU and IFARE, 2002], [38, TWG, 2004]

Other reported data show that per square metre of tinplate 1–2 g/m<sup>2</sup> used solvents arise, which are normally cleaned and recycled on or off site [10, Spain, 2000].

#### Wastes arising from drum coating and printing

Table 10.17 shows emissions data from the coating and printing of drums.

Table 10.17: Emissions from the coating and printing of drums

Waste	6.25 %
Waste	14 tonnes
NB: Typical estimated emissions per million large drums	
Source: 38, TWG, 2004.	

## 10.4 Techniques to consider in the determination of BAT for the coating and printing of metal packaging

In Chapter 17, techniques are discussed which might also be applicable to the coating and printing of metal packaging. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to coating and printing of metal packaging. In Table 10.18, the general techniques relevant for the coating and printing of metal packaging that are described in Chapter 17, and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

**Table 10.18: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### ~~[Conventional solvent-based coating and ink systems]~~

*Conventional techniques have been deleted if they can no longer be considered BAT.*

*This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumptions or emissions*

**Description:** For the general description, see Section 0. ~~Coating and ink materials are typically organic solvent based in the following metal packaging manufacturing processes:~~

- ~~• external coating applied to DWI cans~~
- ~~• decorative inks applied to DWI cans~~
- ~~• sheetfed special applications~~
- ~~• base coat and ink applied to aluminium extruded tubes~~
- ~~• internal and external coating of drums.~~

**Achieved environment benefits:** ~~Reduced cleaning (wash-up) frequency and consumption of materials. Waste materials are cost effectively recycled for solvent recovery.~~

**Cross-media effects:** ~~No data submitted.~~

**Operational data:** ~~Waste gases from sheetfed processes are usually treated as follows:~~

- ~~• coating processes are usually treated~~
- ~~• printing processes are usually dispersed directly to air.~~

~~Waste gases from DWI and drum processes in sheetfed technologies are, depending on local conditions, either treated or dispersed directly to air.~~

~~Waste gases from aluminium extruded aluminium tubes manufacturing processes are usually treated as follows:~~

- ~~• base coat activity is usually dispersed directly to air~~
- ~~• driers are sometimes treated~~
- ~~• decorator ink applicators and clear coat waste gases are typically routed through a caustic scrubber and subsequent drier gases are commonly treated by thermal oxidation.~~

~~**Applicability:** Suitable for coating and printing of metal packaging processes that are subject to specification requirements as follows:~~

- ~~• superior wetting features~~
- ~~• resistance to water permeability~~
- ~~• wet on wet varnish~~
- ~~• improved chemical resistance~~
- ~~• resistance to oil and lubrication contamination.~~

~~**Economics:** No data submitted.~~

~~**Driving forces for implementation:** Product quality and safety.~~

~~**Example plants:** No data submitted.~~

~~**Reference literature:** [75, SEFEL, 2005]~~

~~**[Solvent-based inks in two piece DWI can manufacture]**~~

~~*Conventional techniques have been deleted if they can no longer be considered BAT.*~~

~~*This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumptions or emissions*~~

~~**Description:** The applied printing inks contain 18–38 % organic solvent.~~

~~**Achieved environmental benefits:** No data submitted.~~

~~**Cross-media effects:** No data submitted.~~

~~**Operational data:** DWI printing machines are capable of speeds >2000 cans/minute having 4/6/8 independent sections that are able to apply sequentially up to eight colours and one top coat. Thermal ovens cure the inks at temperatures ranging from 180 to 450 °C for 7 to 60 seconds.~~

~~The inks are cured in a thermal oven and the waste gas can be treated by thermal oxidation. The decorators are designed to allow waste gas extraction. The presses are usually enclosed to enhance waste gas extraction and subsequent treatment.~~

~~**Applicability:** Dry offset processes are commonly applied, however, on newer installations engraving rollers also are utilised. The decorating machines are designed to allow waste gas extraction.~~

~~**Economics:** No data submitted.~~

~~**Driving forces for implementation:** No data submitted.~~

~~**Example plants:** No data submitted.~~

**Reference literature:** [13, DFIU and IFARE, 2002] [29, UKDEFRA, 2003] [38, TWG, 2004]

### 10.4.1 **Material-based techniques [~~Replacement of coatings and inks containing solvents (substitution)~~]**

#### 10.4.1.1 **Water/solvent-based coating and ink systems**

##### **Description**

For the general description, see Section 17.7.2.2. The following are applied to DWI cans:

- exterior coat (bottom not included): 15–45 wt-% organic solvent content;
- interior coat: 10–15 wt-% organic solvent content;
- base coat for the bottom of the can: 80 wt-% organic solvent content.

On aluminium DWI cans, this is:

- interior and exterior coat: 12–16 % organic solvent content;
- coat for the bottom of the can: about 33 % organic solvent content.

On steel drums, this is:

- exterior coat: 5–15 % organic solvent content.

##### **Achieved environmental benefits**

No data submitted.

##### **Cross-media effects**

Changing to water-based means increased energy use (and therefore CO<sub>2</sub> emissions) for dryers and thermal oxidisers. However, if the VOC emission reduction is sufficient and the oxidisers can be shut off, the energy usage may be the same or less (see the ECM REF, Annex 14 on water-based printing).

##### **Operational data**

The exhaust air from the spray application and the dryers is usually treated. Substitute coatings are mainly available for drawn and ironed (DWI) can coating processes.

##### **Applicability**

Aluminium cans are mainly coated with water-based coatings (e.g. lacquers).

##### **Economics**

No data submitted.

##### **Driving force for implementation**

No data submitted.

##### **Example plants**

~~Rexam, Berlin, Germany (tin cans):~~ #123, #116, #118, #119, #113, #111, #117, #124 (inside spray, base coat)

##### **Reference literature**

[13, DFIU and IFARE, 2002] [29, UKDEFRA, 2003] [70, UBA Germany, 2003] [38, TWG, 2004] [78, TWG, 2005]

### 10.4.1.2 Water-based coating systems and compounds in metal packaging manufacture based on sheetfed technology

This section gives information on three-piece cans as well as the other metal packaging which is not DWI.

#### Description

For the general description, see Section 17.7.2.2. The following water/solvent-based coating systems are applicable to metal packaging as follows:

- three-piece cans for food, drinks, aerosols and speciality products;
- three-piece cans welded side stripe protection; water-based coatings may be applied onto the side stripe of weldings;
- ends, caps, lids and closures for three-piece cans, jars and bottles;
- two-piece non-DWI cans.

#### Achieved environmental benefits

Reduction in organic solvent emissions because no organic solvents are used. Reduced health and safety risks for operators of coating machines because of a reduced exposure to solvents. Reduced fire and explosion risks

#### Cross-media effects

Increased machine cleaning frequency and downtime. Increased sludge in the extract system (condensate and resin). ~~Reduced health and safety risks for operators of coating machines because of a reduced exposure to solvents. Reduced fire and explosion risks.~~ Requires thermal drying ovens.

#### Operational data

Exhaust air from the coating process and the dryers is usually treated. Water-based coating systems have to be stored in a frost-free environment. ~~Reduced health and safety risks for operators of coating machines because of a reduced exposure to solvents. Reduced fire and explosion risks.~~

#### Applicability

Water-based compounds are often available and applied. Wet-on-dry applications only subject to quality parameters. Applied to metal packaging components, caps and closures.

#### Economics

Process pumps and pipework need to be of high quality steel. Increased maintenance costs for wear to scraper blades, increased extract system cleaning costs. Investment necessary for drying ovens and high quality supply of distribution pipework systems.

#### Driving force for implementation

Legal environmental compliance.

#### Example plants

Impress Hoogeveen and Impress Deventer both in the Netherlands, #113

#### Reference literature

[29, UKDEFRA, 2003], [38, TWG, 2004]

### 10.4.1.3 Sheetfed coating

*To be moved to application techniques (10.4.2) or be deleted because it contains the same information as 10.4.1.2*

This section gives information on three-piece cans as well as the other metal packaging which is not DWI.

**Description**

Waterborne materials are suitable for certain metal packaging products but are limited to polyesters, acrylic and epoxyphenolic (excludes organosol), however, all waterborne coatings contain some organic solvents, mainly to aid wetting.

**Achieved environmental benefits**

Reduced emissions of organic solvents. Reduced health and safety risks for operators of coating machines because of a reduced exposure to solvents. Reduced fire and explosion risks.

**Cross-media effects**

Increased scraper blade wear and condensate production.

**Operational data**

Downtime for cleaning is typically 30 minutes longer than for solvent-based materials.

**Applicability**

Suitable for wet-on-dry applications only. Applied to metal packaging manufacture based on sheetfed technology.

**Economics**

Approximately the cost is neutral between waterborne and solvent-based.

**Driving force for implementation**

Compliance with the reduction scheme of solvents.

**Example plants**

Impress Hoogeveen, the Netherlands.

**Reference literature**

[38, TWG, 2004]

**~~[Repair spray]~~**

*Proposed for deletion*

~~This section gives information on cans with easy open ends only.~~

**~~Description~~**

~~Steel easy open end 'scoring' takes place after the primary coating and press operation and this scoring must be repair sprayed to prevent corrosion of the steel. Suitable lacquers are currently available in organic solvent based lacquers only.~~

**~~Achieved environmental benefits~~**

~~No data submitted.~~

**~~Cross-media effects~~**

~~Organic solvents are normally dispersed direct to the air.~~

**~~Operational data~~**

~~Good wetting properties and resistance to surface oils.~~

**~~Applicability~~**

~~Steel easy open ends. Applied to metal packaging manufacture based on sheetfed technology.~~

**~~Economics~~**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[38, TWG, 2004] [78, TWG, 2005]

**10.4.1.4 Powder spray side strip coating**

**Description**

See Section 17.7.2.8.

**Achieved environmental benefits**

No organic solvent emissions.

**Cross-media effects**

The film weight is typically 10 times that needed for a liquid side stripe.

**Operational data**

Electrostatic control of spray is necessary.

**Applicability**

Applied to metal packaging manufacture based on sheetfed technology. Inside side stripe protection of cans for aggressive filling goods. Powder coatings may be applied onto the welding and are called 'side stripes'. Powder coatings are used for three-piece welded can side stripe protection.

**Economics**

Applied costs of powder are higher than for liquid lacquers.

**Driving force for implementation**

Environmental legislation.

**Example plants**

Impress Deventer, the Netherlands. #112 (side stripe powder), #121,

**Reference literature**

[29, UKDEFRA, 2003] [38, TWG, 2004]

**10.4.1.5 Coil-coated materials**

This section gives information on three-piece cans as well as the other metal packaging which is not DWI.

**Description**

See Section 17.7.2.9. Coil-coated materials can be applied.

**Achieved environmental benefits**

Significant reduction of VOC emissions dependent on the coating activities that are replaced by applying coil-coated materials.



**Cross-media effects**

Loss of materials as skeletal waste at an average of 20 % which includes coated material.

**Operational data**

No data submitted.

**Applicability**

Applied only to some ends and domes for aerosol cans.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

~~No data submitted.~~ #111

**Reference literature**

[13, DFIU and IFARE, 2002] [78, TWG, 2005]

**10.4.1.6 Pre-coated coil****Description**

This technique can be used for the production of three-piece cans as well as for other metal packaging which is not DWI.

**Achieved environmental benefits**

No organic solvent emissions at the metal packaging manufacturing facility.

**Cross-media effects**

Process metal scrap (shred) contains coating.

**Operational data**

No data submitted.

**Applicability**

Applied to metal packaging manufacture based on sheetfed technology and to coil fed processes. Pre-coated coil is available from a limited number of metal suppliers and is suitable for selected ends, closures and deep-drawn closures only. Not suitable for DWI cans.

**Economics**

No data submitted.

**Driving force for implementation**

Environmental licensing or there is a need to sub-contract out the coating activity.

**Example plants**

~~No data submitted.~~

#120 (use of polymer laminated coil for ends production)

**Reference literature**

[38, TWG, 2004]

### 10.4.1.7 UV compounds (varnish and inks)

#### Description

See Section 17.7.2.4. UV inks are applied to a wide range of products: aerosols, food, general line, closures, and caps. UV varnishes are also used for aerosols, food and some general line.

#### Achieved environmental benefits

No organic solvent emissions. No thermal curing ovens and associated energy and emissions implications.

#### Cross-media effects

Ozone is emitted.

#### Operational data

Caution must be exercised with the use of UV materials and its suitability for any fill product.

#### Applicability

This technique applies to three-piece cans as well as the other metal packaging which is not DWI.

Use of UV inks for metal packaging has increased in non-food applications and is commonly applied. Applied to metal packaging manufacture based on sheetfed technology. UV lamp curing replaces conventional thermal drying ovens. Applications of UV varnish are highly limited by standards in tooling flexibility and resistance to abrasion.

#### Economics

No data submitted.

#### Driving force for implementation

Environmental legislation compliance.

#### Example plants

~~No data submitted.~~ #112, #121, #122, #123, #116, #118, #119, #114, #111, #120 (only used UV-cured inks in printing), #117, #124

#### Reference literature

[29, UKDEFRA, 2003] [38, TWG, 2004]

## 10.4.2 Application of coatings and ink

### 10.4.2.1 Roller coating

#### Description

A coating is applied from a rotating rubber roller onto a flat (sheet or coil) or cylindrical (cans) substrate. The coating thickness can be adjusted by variation in the pressure between the roller and the substrate. In metal packaging manufacturing, roller coaters are used for sheets coated inside and out in different passes, and for beverage cans and the outside of monobloc aerosols.

#### Technical description

A train of steel rollers feeds the rubber roller with coating. A wet film weight of up to 30–35 micron can be achieved when rubber rollers rotate in the same direction as the sheet. Nowadays, the rubber roller is also fed by a single steel roller of the anilox type (cell structure) in combination with a doctor blade. Sheetfed application also requires a steel support roller under the substrate. Sheet application also means a gap between the sheets, causing contamination on the support roller, which must be removed by a scraper blade system.

In sheetfed application, only lacquers with a certain viscosity can be applied, in contrast to the reverse roller application as used in coil application. Roller coaters are normally combined with a curing step as the sheets are directly staggered and are therefore combined with a thermal oven and/or UV curing step or a combination.

Coating of cylindrical surfaces requires a high rotation speed of the application roller which leads to misting of the wet lacquer. As a consequence, frequent cleaning of the machine is necessary. The metal parts of the roller coater in contact with the coating are cleaned in a cleaning machine operating on water with detergents. The rubber rollers are manually cleaned with a mild solvent.

The most commonly used materials are rubber based on EPDM, butyl rubber and PU. The choice depends on multiple factors.

#### **Achieved environmental benefits**

The introduction of anilox rollers reduces the amount of lacquer applied due to better production margins and the option of spot coating.

#### **Environmental performance and operational data**

Efficiency is almost 100 %. Coaters are normally equipped with air extraction to minimise the VOCs for health and safety reasons. All solvents are extracted in the oven and can then be treated.

#### **Cross-media effects**

Coatings used can be diluted to achieve good viscosity, however more and more coatings are ready-for-use. Solvents are used to clean the roller coater. But nowadays a cleaning machine is often used for parts of the coater in contact with the coating.

#### **Technical considerations relevant for applicability**

Roller coaters for metal packaging can be used for all types of coatings including water-based and UV varnishes.

In some cases, an anilox roller system is used to improve the flow of the coating on the substrate. Also, pretreatment of the surface is possible when placing this between the feeder roller and the roller coater of the line (e.g. flame treatment).

#### **Economics**

The roller coater is not a stand-alone piece of equipment but is part of a line including an oven and equipment to transport the sheets or cans through the oven and the roller coater.

Additional process equipment is needed; this makes such a line expensive. *TWG please clarify: does this mean the rest of the line equipment or there is ancillary equipment just for the roller coater?*

#### **Driving force for implementation**

Almost 100 % coating efficiency on sheets. Mostly the required film weight is achieved in one pass. Flexibility, as every type of lacquer needed for three-piece operations can be applied. Coating of ends is possible because of spot coating and for body application welding margins can be made on the sheet by the use of a roller coater.

#### **Example plants**

#121, #112, #108, #122, #123, #118, #119, #114, #111, #120, #117, #124

#### **Reference literature**

~~[Rollers for two-piece DWI can manufacture]~~

**Description:** See Section 17.7.3.1. Roller coating and dry offset is commonly used for the application of the external coating and inks.

**Achieved environmental benefits:** Optimum material utilisation.

**Cross-media effects:** Sometimes the exhaust air from the coating and printing processes are dispersed directly to air.

**Operational data:** The applicator rollers are enclosed and excess coating material is collected and returned to the reservoir.

**Applicability:** Roller coaters are commonly used for the application of the external coating and dry offset printing for the application of inks.

**Economics:** No data submitted.

**Driving forces for implementation:** Optimum material utilisation.

**Example plants:** Rexam, Berlin, Germany (steel cans).

**Reference literature:** [13, DFIU and IFARE, 2002] [29, UKDEFRA, 2003] [70, UBA Germany, 2003] [38, TWG, 2004]

#### **[Rollers for sheetfed technology]**

This section gives information on three piece cans as well as the other metal packaging which is not DWI.

**Description:** See Section 17.7.3.1. Layers of coatings are accurately controlled to typically 3 to 10 microns.

**Achieved environmental benefits:** Optimised lacquer application and reduction of organic solvent emissions.

**Cross-media effects:** No data submitted.

**Operational data:** The applicator rollers for coating sheets are enclosed and excess coating material is collected and returned to the reservoir.

**Applicability:** Roller coaters are used exclusively for coating the sheets. Side stripes can also be applied by using rollers. The metal packaging industry in selected operations uses continuous and spot coating rollers for applying lacquers.

**Economics:** Coating material savings.

**Driving forces for implementation:** Cost and quality control of coating application.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002] [29, UKDEFRA, 2003], [38, TWG, 2004]

#### **[Rollers for aluminium extruded tube manufacture]**

**Description:** See Section 17.7.3.1. Roller coaters are used for applying the base coat; the cylinder rotates and the roller is static. The pick-up roller runs through a reservoir containing the coating material, excess material is then removed by the metering system and is fed back into

the reservoir. After the printing process, an overvarnish (clear coat) is applied using the rollers. The coating station is usually enclosed and waste air is extracted, and treated by a scrubber unit. The subsequent drying process is then abated with a thermal oxidiser.

**Achieved environmental benefits:** Reduction of solvent emissions to air.

**Cross-media effects:** No data submitted.

**Operational data:** No data submitted.

**Applicability:** No data submitted.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002] [29, UKDEFRA, 2003] [38, TWG, 2004]

#### 10.4.2.2 Compressed air spraying

##### Description

For a general description, see Section 17.7.3.14.

##### Achieved environmental benefits

The application efficiency of the interior spraying ranges from 93 % to 97 % for two-piece DWI can manufacture.

##### Cross-media effects

No data submitted.

##### Operational data

The overspray is commonly separated by applying dry filter systems. The overspray coating is not reused or recycled.

##### Applicability

Compressed air spraying is commonly applied for the application of internal coating for two-piece DWI can manufacture and in manufacture of metal packaging based on sheetfed technology.

##### Economics

Minimises the use of lacquer through targeted profile application.

##### Driving force for implementation

Environmental benefits and economic reasons.

##### Example plants

Rexam, Berlin Germany (steel cans). #108,

##### Reference literature

[13, DFIU and IFARE, 2002] [29, UKDEFRA, 2003] [70, UBA Germany, 2003] [38, TWG, 2004]

### 10.4.2.3 Airless spraying

*[Proposed for deletion as a conventional technique]*

#### **Description**

~~See Section .~~ Side stripes can be applied by using airless spray guns. Airless spraying (electric) is commonly used for the application of the internal coating.

#### **Achieved environmental benefits**

The application efficiency of the interior spraying is 90 % in the manufacture of two-piece DWI cans. Minimises the use of lacquer through targeted profile application.

#### **Cross-media effects**

None.

#### **Operational data**

The overspray is commonly collected by dry filter systems. The overspray coating is not reused or recycled.

#### **Applicability**

Airless spray is commonly applied for the internal coating of two-piece DWI can manufacture and in metal packaging manufacture based on sheetfed technology.

#### **Economics**

High application efficiency and lower raw material use, see Driving force for implementation below.

#### **Driving force for implementation**

Reduces air emissions and is cost-effective.

#### **Example plants**

Rexam, Berlin, Germany (steel cans). #123, #124

#### **Reference literature**

[13, DFIU and IFARE, 2002] [29, UKDEFRA, 2003] [70, UBA Germany, 2003], [38, TWG, 2004]

#### **[Electrostatic spraying]**

~~**Description:** Side stripes coated with powder coating are applied by using electrostatic spray guns.~~

~~**Achieved environmental benefits:** No data submitted.~~

~~**Cross-media effects:** No data submitted.~~

~~**Operational data:** The excess coating material is collected and returned to the reservoir.~~

~~**Applicability:** Metal packaging manufacture based on sheetfed technology.~~

~~**Economics:** No data submitted.~~

~~**Driving forces for implementation:** No data submitted.~~

~~**Example plants:** No data submitted.~~

~~**Reference literature:** [29, UKDEFRA, 2003]~~

**[Powder spraying]**

*Proposed to delete – related to the use of powder coatings*

**Description:** ~~The metal packaging industry uses electrostatic spray equipment for three piece welded can side stripe applications.~~

**Achieved environmental benefits:** ~~Closed loop recirculation of powder prevents dust emissions.~~

**Cross-media effects:** ~~None.~~

**Operational data:** ~~No data submitted.~~

**Applicability:** ~~Used for three piece cans with lacquered side striping. Applied in metal packaging manufacture based on sheetfed technology.~~

**Economics:** ~~Applied material costs are higher than for liquid side stripe lacquers.~~

**Driving forces for implementation:** ~~Environmental compliance.~~

**Example plants:** ~~No data submitted.~~

**Reference literature:** ~~{38, TWG, 2004}~~

**10.4.2.4 Liquid side stripe**

*Moved here from section 10.4.1 since it is an application techniques*

This section gives information on three-piece cans only.

**Description**

A lacquer side stripe is applied to the external and internal areas of the welded region of the can cylinder. Film weight per typical can is approximately 0.02 g/can and the type of lacquer is selected according to the aggressive nature of the products that must be filled into the can. Waterborne materials are available for selective can products after having undergone extended qualifying pack tests (see example plants below).

**Achieved environmental benefits**

Reduced organic solvent emissions.

**Cross-media effects**

No data submitted.

**Operational data**

Waterborne lacquers may be used with standard side striping equipment. Reduced health and safety risks for operators of coating machines because of a reduced exposure to solvents. Reduced fire and explosion risks.

**Applicability**

Waterborne materials are not suitable for inside side striping of cans for aggressive products.

**Economics**

Approximately the cost is neutral between waterborne and solvent-based.

**Driving force for implementation**

Compliance with the reduction scheme of solvents.

**Example plants**

~~No data submitted.~~ #112 (project to substitute SB lacquer with WB), #121, #116 (WB), #120

**Reference literature**

[29, UKDEFRA, 2003] [38, TWG, 2004] [78, TWG, 2005]

**10.4.2.5 Curtain coating**

**Technical description**

This is a coating technique used for the external anti-corrosion protection of DWI cans for food products where a plain (non-decorative) protective finish is required. The coating normally also contains a lubricant to aid can mobility during subsequent manufacture and filling. The coating is applied by the passage of previously cleaned and rinsed upturned (base uppermost) cans, en masse on a wide conveyer belt, under single or multiple waterfalls or curtains of a dilute waterborne 'washcoat'. The excess wet coating runs off the cans into a capture and recirculating system, then the can immediately enters an oven to evaporate the liquid carrier and cure the remaining solids into a protective film. The curtain coater is normally constructed as an integral part of the overall can cleaning, rinsing and drying facility. The continuous ingress of deionised water on the can from the prior can rinsing process dilutes the washcoat in the system which is reconcentrated by ultrafiltration and/or periodic additions of concentrated washcoat. The washcoat is primarily waterborne but with a small VOC content to aid wettability of the can surface.

**Achieved environmental benefits**

Use of waterborne coating materials minimises solvent content.

**Cross-media effects**

No data submitted.

**Operational data**

When cans are not to be decorated as is the normal case for food cans, then a clear external protective coat is applied to the upturned can via a curtain coater. Curtain coating systems incorporate a closed loop capture and recirculating facility.

**Applicability**

Food cans external protection. Applied in two-piece draw and wall iron (DWI) can manufacture.

**Economics**

Optimisation of materials.

**Driving force for implementation**

Cost and environmental benefit.

**Example plants**

No data submitted.

**Reference literature**

[29, UKDEFRA, 2003] [38, TWG, 2004]

**[Radiation curing]**

~~For a general description, see Section 17.7.2.4.~~

~~delete – related to the use of radiation-cured coatings~~



### 10.4.3 Printing

#### 10.4.3.1 Lithography (wet offset) for sheetfed technology

This section gives information on three-piece cans as well as the other metal packaging which is not DWI.

##### **Description**

For a general description, see Section 10.2. Modern lithographic printing presses are capable of speeds in excess of 6 000 sheets per hour. The number of printing colours employed is design specific, e.g.:

- milk powder containers can have 10/11 colours;
- promotional metal containers can have 13/14 colours.

##### **Achieved environmental benefits**

Printing inks used for lithographic processes contain typically less than 10 % organic solvent resulting in low VOC emissions.

##### **Cross-media effects**

The organic solvents are typically dispersed directly to the air from the drying ovens.

##### **Operational data**

Printing lines are comprised from between one and six printing decks and can apply from one and six colours in sequence. Some designs are achieved with a four colour process set; whilst others are achieved with the six colour hexachrome printing set. However, a large proportion of designs is still achieved using spot colours (i.e. inks colour matched to a specific shade to meet the needs of the design).

##### **Applicability**

Common technology used in the flat sheet metal packaging printing industry.

##### **Economics**

No data submitted.

##### **Driving force for implementation**

No data submitted.

##### **Example plants**

This technique is commonly applied, #112 (UV-curing inks), #121, #111 (UV curing inks), #120 (flat sheet coating lines)

##### **Reference literature**

[29, UKDEFRA, 2003], [38, TWG, 2004]

#### 10.4.3.2 Waterless lithography

##### **Description**

See Section 11.4.2.2

Waterless offset is an offset printing technique that does not use water/oil separation to ensure that the ink only covers the image carrying parts of the plate: separation is achieved by special plates and inks. In normal offset, the plate is hydrophobic in the image carrying places and hydrophilic elsewhere. Water is used to make sure that the oily inks do not attach to the non-image carrying parts. In waterless offset, the non-image carrying parts have a coating that achieves the same effect. No water is needed.

**Achieved environmental benefits**

Savings of resources, raw materials and emissions from dampening solutions are eliminated. Reduced set-up times for decoration changes. To reduce the material consumption for the exterior varnish, the can can be directly printed via the offset process and then coated with a thin layer of varnish (clear coat) for protection of the print.

**Cross-media effects**

Chilling of the plant is required.

**Operational data**

No data submitted.

**Applicability**

This process is normally used when print registration to the product is not possible such as on circular surfaces; examples are drink cans, caps and extruded aluminium tubes. This technique can be applied for selected metal packaging products. In new installations, engraving rollers are utilised for the application of the printing ink.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

~~This technique is commonly applied.~~

No example plants submitted

**Reference literature**

[13, DFIU and IFARE, 2002] [29, UKDEFRA, 2003] [38, TWG, 2004]

**10.4.3.3 Waterless offset lithography for aluminium extruded tube manufacture**

**Description**

See Section 10.4.3.2. The cured base coat provides the key for the subsequently printed design, which is applied via a multicolour decorator using the waterless offset process.

**Achieved environmental benefits**

No data submitted.

**Cross-media effects**

No data submitted.

**Operational data**

Inks are spooned by hand to the reservoir rolls and a precise system of rolls accurately measures each colour separately onto the application roll. Usually, there is a fume extractor at the decorator, which is ducted to the air once it has passed through a caustic scrubber.

**Applicability**

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No example plants submitted

**Reference literature**

[29, UKDEFRA, 2003]

**10.4.4 Curing****10.4.4.1 Ultraviolet curing of coatings for metal packaging****Description**

UV curing is a process where ultraviolet light is used to initiate a photochemical reaction that generates cross-linking and polymerisation between resins.

**Technical description**

UV curing can be used for the printing and coating in the metal packaging industry. Its main application is for the outside of cans as there are restrictions concerning food contact. It is a low-temperature and solvent-free process. Low-molecular-weight resins/monomers, with a low viscosity, start a rapid chemical reaction/cross-linking. This reaction is initiated by the formation of reactive cleavage products of the so-called photo-initiators. This cleavage process is started if the photo-initiator is in contact with UV light of a specific frequency. Different types of coating demands ask for different photo-initiators. The UV light is generated by the use of doped mercury lamps, with the types used depending on the end use and the corresponding photo-initiator. The end use is mainly flat sheets and the use of UV coating for the rim of a beverage can's base. Although the process is solvent-free, extraction is still necessary due to the formation of ozone and a need to avoid possible odour problems caused by the used monomers. The cleavage products of the photo-initiator are by theory bound to the backbone of the formed polymer.

**Achieved environmental benefits**

UV curing uses solvent-free lacquers / printing inks. In combination with a lower amount of energy compared to the thermoset lacquers which needs a long thermal oven, CO<sub>2</sub> emission is also avoided..

**Environmental performance and operational data**

UV curing systems are often combined with the roller coaters that are normally used in metal packaging manufacturing. However, combinations of UV application and conventional gas ovens can also be found. UV curing systems also require less space. UV varnishes and UV printing inks have a limited adhesion towards metal and can therefore not be used for some applications.

**Cross-media effects**

The application and curing of UV coatings will still need extraction for health and safety reasons.

**Technical considerations relevant for applicability**

UV curing is currently limited to the outside of cans due to restrictions relating to food contact legislation. Also, direct application on electrolytic tinplate is more difficult due to limited adhesion. New UV resin technologies, like cationic curing, have less restriction concerning smell and will have more possible end uses than the old technologies. New types of UV light sources are developed like UV-LED, with less energy consumption, longer lifetimes and a better curing control. However, the tighter frequency range of LEDs requires lacquer modifications when changing from mercury lamps to LEDs.

There are presently no UV lacquers available which suit the high-speed roller coater application for DWI cans.

### **Economics**

The cost depends greatly on whether UV curing equipment is installed in an existing line or in a new line.

### **Driving force for implementation**

Lower energy consumption, lower emission and in typical cases economic reasons.

### **Example plants**

.#112, #121, #122, #123, #116, #118, #119, #114, #111, #120 (only used UV-cured inks in printing), #117, #124

### **Reference literature**

## **10.4.5 Waste gas treatment**

### **10.4.5.1 Dry particle filter systems**

For a general description, see Section 17.10.4.5. This technique is commonly applied in two-piece DWI can manufacture and metal packaging manufacture based on sheetfed technology for the removal of coating particles.

[13, DFIU and IFARE, 2002], [38, TWG, 2004] [155, TWG, 2016]

### **10.4.5.2 Electrostatic filter**

For a general description, see Section 17.10.4.4. This technique is commonly applied for the removal of coating particles. Electrostatic filters are not in use in the can-making industry.

[38, TWG, 2004]

### **10.4.5.3 Thermal oxidation**

For a general description, see Section 17.10.5.2. VOC emissions can be reduced effectively by the post-combustion of waste gases from dryers used on coating and printing presses and other printing activities. Heat recovery can be applied for heating of pretreatment rinsing water and it is state-of-the-art in some industries.

This technique is applied to dryers. However, it is less common for coating and printing applicators. It is not typically applied when the solvent reduction scheme has led to the use of waterborne materials. This technique is applied to the following sectors:

- two-piece draw and wall-ironed (DWI) can manufacture;
- metal packaging manufacture based on sheetfed technology;
- aluminium extruded tube manufacture;
- drums.

[29, UKDEFRA, 2003] [38, TWG, 2004] [78, TWG, 2005]

### **10.4.5.4 Catalytic oxidation**

For a general description, see Section 17.10.5.6. The use of catalytic oxidation is under development.

[29, UKDEFRA, 2003]

#### **10.4.5.5 Adsorption to activated carbon**

For a general description, see Section 17.10.6.3. Adsorption wheels can be applied as a pretreatment to thermal oxidation. Applied in the two-piece DWI can manufacture sector. [13, DFIU and IFARE, 2002], [38, TWG, 2004]

#### **10.4.5.6 Biological treatment**

For a general description, see Section 17.10.7. The use of biological treatment is under development. [29, UKDEFRA, 2003]

### **10.4.6 Waste water treatment**

#### **10.4.6.1 Flocculation/sedimentation**

For a general description, see Sections 0 and 0. This is commonly applied to the waste water generated from a can cleaner. It is used in the case of DWI cans. For the production of steel cans, a discharge tin concentration of < 2 mg/l to a maximum of 4 mg/l has been reported. [13, DFIU and IFARE, 2002], [38, TWG, 2004]

#### **10.4.6.2 Ultra and nanofiltration**

For a general description, see Section 17.11.8. This technique can be applied to waste waters generated from the pretreatment processes of the following industries:

- two-piece draw and wall iron (DWI) can manufacture;
- metal packaging manufacture based on sheetfed technology;
- aluminium extruded tube manufacture.

It is not used currently for treating waste waters from can-making plants. [38, TWG, 2004]

WORKING DRAFT IN PROGRESS

## 11 HEATSET OFFSET WEB PRINTING

### 4.1.1.1. Offset general

## 11.1 General information

[4, Intergraf and EGF, 1999] [78, TWG, 2005]

*TWG please provide updated information for 11.1 and 11.2*

Offset is a printing process using an image carrier in which the printing and non-printing areas are on the same plane. The non-printing area is treated to attract water and thus reject the greasy ink. The printing area is treated to receive and transmit ink to a rubber-coated cylinder and from there the surface to be printed. Heatset means an offset printing process where evaporation takes place in an oven where hot air is used to heat the printed material. Most offset inks do not dry by evaporation, but by oxidation or absorption in the paper. Heatset inks are the exception. They are the unique offset ink, drying largely through evaporation.

Emissions to air arise primarily from the organic solvents contained in inks. Solvents used in cleaning and dampening solutions (commonly isopropanol) are also important sources of VOC emissions. Solvents driven off through evaporation from the inks may be discharged untreated or destroyed via thermal oxidation. Cleaning techniques range from wiping equipment with a solvent cloth to the use of enclosed cleaning units designed to recycle solvents.

## 11.2 Applied processes and techniques in heatset offset printing

Offset printing is a planographic printing technique, i.e. where the image and non-image areas are on the same plane as the image carrier. The non-printing areas are kept free of ink by being ink-repellent while, on the other hand, the printing areas are ink-receptive. This is achieved by the offset ink being oil-based and the non-printing areas are kept clean with water or water-based solutions, as the water and oil repel each other. The additives to the water are usually isopropyl alcohol (IPA) or isopropyl alcohol substitutes/extenders, etc. However, waterless printing is also possible, where the non-printing areas are kept free of ink by an ink-repellant coating [8, Nordic Council of Ministers, 1998] [11, IMPEL, 2000, 38, TWG, 2004].

Offset is currently the most widely used printing process, due to its versatility, speed, quality, and cost-effectiveness achieved by a series of developments in plates and extending their life by the offset process, improved materials allowing higher quality and ease of use with photosetting.

Offset machines come in a variety of sizes, from the small offset sheetfed press which prints A3 through the large sheetfed press of 1200 x 1600 mm or more dealing with many colours at a time, to the large web presses printing paper two metres wide at very high speeds. The versatility of the process allows the production of a very wide variety of printed products [38, TWG, 2004].

Modern web presses are built with eight units which makes it not only possible to print eight colours on one side of the substrate, but also to print four colours on each side in one run. Modern presses are also built to meet an increasing demand for automation and new presses come equipped with automatic cleaning systems for plates, blankets and impression cylinders, automatic systems for changing plates, etc. [8, Nordic Council of Ministers, 1998] [38, TWG, 2004].

Depending on the type of printing process, substrate or products printed, the offset process is further divided into subprocesses [11, IMPEL, 2000] [38, TWG, 2004]:

- sheetfed offset;
- heatset web offset;
- coldset offset.

Offset inks used in sheetfed and coldset offset dry through adsorption into the paper and by oxidation. With glossy paper especially, adsorption happens too slowly for modern fast printing presses. Modern high speed webfed offset presses, onto which non-adsorbent paper is printed, are, therefore, equipped with forced hot air drying systems; these offset printing processes are called 'heatset'.

### **The dampening unit**

[4, Intergraf and EGF, 1999] [78, TWG, 2005]

The task of the dampening unit in an offset machine is to wet the surface of the printing plate with a uniform film of moisture during printing, so that when inking follows, it only adheres to the plate in the image areas.

Film dampening units are the most widely used. These put down a thin film of dampening solution onto the plate using a series of rollers which distribute the liquid in a controlled and consistent way.

This dampening unit construction operates either with water or, in many cases, with a water-isopropanol solution, (or in some cases, ethanol). Note that ethanol has a higher OFP; see Section 17.6.2) and uses the technologically favourable (in respect of printing) properties of



IPA. The acidic IPA-based dampening solutions (with a pH of normally between 4 and 5.5) enhance the desensitising action in the non-image areas and maintains their hydrophilic properties. Other commonly used additives are: gum Arabic, corrosion inhibitors, wetting agents, drying stimulators, fungicides, antifoaming agents, etc. [8, Nordic Council of Ministers, 1998].

IPA has a lower surface tension than water and, therefore, has the capacity to wet the plate more effectively. The process is complex, but empirically, it is generally accepted that a thinner film of dampening solution can therefore be deposited on the plate, which allows greater control, especially on high quality print jobs. Set up times can be reduced, so less paper is wasted. The printing can be sharper, and less water on the plate means fewer problems with paper stretch.

The extent of IPA use varies from country to country, with the make and model of the press, the paper type and the difficulty of the job. Since IPA evaporates faster than water, circulation units for the dampening solution and the dosing of IPA or ethanol are, in many cases, fitted with a cooling unit in order to reduce evaporation. The dampening solution is continuously pumped towards the press, and the excess returns to the container via an overflow. The concentration of IPA in the container is measured continuously. IPA is added automatically when the concentration diminishes.

### **The inking unit**

[4, Intergraf and EGF, 1999]

The inking unit found on offset presses varies with the size of the press and the job it is designed to do. Large presses and those designed to print quality work are likely to have many rollers in the ink train to ensure uniform ink distribution (more than 20 rollers is not unusual). Three or more of these actually apply the ink to the plate, with the quantity of ink being applied at any point across the width of the plate being adjustable by turning ink screws by hand or, increasingly these days, this can be computer controlled.

Rollers are made of, or covered with, different materials, such as steel, synthetic rubber or polyurethane. From time to time, the ink needs to be removed by cleaning.

Drying may be accelerated by infrared heating or, alternatively, special inks may be used which are cured by ultraviolet radiation [4, Intergraf and EGF, 1999].

### **Cleaning**

Depending on the printed image, the substrate and the ink being used, paper debris such as dust and lint, and printing ink constituents can build up on the rubber blanket. The quality of printing then declines so the blanket surface has to be cleaned. With smaller and medium format machines, cleaning is carried out by hand and predominantly with wipes and cleaning agents. In the case of larger sheetfed machines, the use of automatic blanket cleaning units (with cleaning programmes) is increasing.

Obviously, the image has to be removed from the blanket between jobs. Both in manual and automated blanket cleaning, mainly hydrocarbons and water (to remove paper solids on the rubber blanket) are used. The cleaning agents are predominantly naphthenic and aliphatic hydrocarbons. Increasingly high-boiling hydrocarbons with a flashpoint of  $> 100\text{ }^{\circ}\text{C}$  and vegetable oil esters and/or mixtures of hydrocarbons and vegetable oil esters are used.

When a print run (or shift) is finished and the next printing work requires the use of other inks, cleaning of the inking units (ink rollers, ink ducts) and printing units (impression cylinders, etc.) is necessary. In the case of oxidative drying printing inks, such cleaning work may also be necessary at the end of each shift. To clean the inking rollers, cleaning agents are sprayed on and the cleaning residues are wiped off. Sheetfed machines of modern design are increasingly fitted with automatic cleaning units. The cleaning of the ink ducts is done either by hand or in

special cleaning units, usually with the same materials as used for blanket cleaning [38, TWG, 2004].

*All the general introduction to the printing industries and technologies in the current BREF Sections 2.1 and 2.2 have been moved to Annex 21.9. We welcome comments whether this should be edited to produce a useful background annex and context for the three technologies included (e.g. to answer questions why newspaper printing is not considered in the BREF) or it should be deleted.*

WORKING DRAFT IN PROGRESS

## 11.3 Current consumption and emission levels in heatset web offset printing

### The printing industry as a whole

An overview of the printing industry is given in the preceding sections of Chapter 2. The consumptions and emissions given in this section are from the information exchange to the three largest processes most likely to exceed the thresholds in Annex 1 (6.7) to the IPPCD. Other printing processes may be found in the same installation as associated activities, or occasionally operating above the threshold.

### Heatset web offset

#### Mass balances—heatset

In 1999, the results of an inventory amongst heatset printing plants in Germany were reported. One of the results of this inventory was that the performance data from different units of different plants were compared and used to simulate a virtual plant that could meet the legal requirements, especially those of the Solvent Emissions Directive. This virtual plant is not an existing plant, but made up of information from well performing units from different existing plants representing good practice and good environmental performance. This plant could feasibly exist.

In this section, the mass balances of the theoretical virtual plant from this inventory are reported. Actual plants can vary widely with production parameters, such as ink coverage, run length, type of paper, etc. [38, TWG, 2004]. However, it should be noted from **Error! Reference source not found.** [38, TWG, 2004] that:

- waste gas treatment usually operates at 700–800 °C, not 900 °C
- the percentage of IPA is not defined: w/w or v/v.

The operational data and production conditions of the virtual plant are shown in **Error! Reference source not found.** and **Error! Reference source not found.**. The mass balances of this virtual heatset offset plant are shown in Table and **Error! Reference source not found.** shows the VOC balance.

<b>Machines</b>	2 x 32 pages heatset offset machine; 4 blanket to blanket units; web width: 1260 mm; cylinder circumference: 890 mm; max. press speed 17 m/s; average velocity approx. 13 m/s at production run.  Total power supply: 1134 kW for press speed up to 14.8 m/s; Electricity consumption at an average press speed of 13 m/s: 996 kW of which approx.: <ul style="list-style-type: none"> <li>• 2 x 470 kW power supply printing press (2 x 295 kW motor power supply; 2 x 120 kW auxiliary drives (printing unit, auxiliary aggregates, control); 2 x 19 kW air blast; 2 x 30 kW roller bearing, 2 x 6 kW remoistening unit)</li> <li>• 2 x 6 kW power supply paper reel transport system</li> <li>• 2 x 91 kW power supply cooling centre</li> </ul>
<b>Products</b>	Commercial printing, e.g. advertising supplements; weekly papers
<b>Printing substrate</b>	Web printing papers with an average weight of approx. 60 g/m <sup>2</sup>
<b>Printing ink</b>	Heatset ink (vapour pressure <0.01 kPa at 20 °C; mineral oil content = 35 % of which about 90 % evaporates in the drier)
<b>Dampening solution</b>	Water (max. 10 °dH), 8 % IPA, 3 % other dampening solution additives
<b>Drier</b>	2 x direct combustion (natural gas), temperature (paper web exit): 120–140 °C, waste gas volume flow approx. 7200 Nm <sup>3</sup> /h (at 13 m/s production run), ventilator:

	72 kW
<b>Waste gas treatment</b>	1 x regenerative thermal oxidation (thermoreactor), combustion chamber approx. 900 °C, VOC destruction efficiency: 99 %. Purified gas exit temperature at 140 °C; heat recovery: 93 % thermal efficiency.  Heating up with 2100 kW gas, normal operation 2 x 700 kW gas. 2 x 200 kW electricity demand (ventilators); electricity consumption 1900 kW/yr, auxiliary combustion approx. 15 kW gas (at 13 m/s; 1.2 g/m <sup>2</sup> ink per page)
<b>Cleaning agents</b>	20 % roller/blanket for cleaning by hand (100 % VOC; vapour pressure 0.05 kPa at 20 °C) and 80 % blanket for clean up device (0 % VOC; vapour pressure <0.01 kPa at 20 °C), re usable solvent wipes (40 gram dry weight/item)

**Table: Operational data of a virtual heatset offset plant**  
[18, UBA Germany, 2003]

<b>Production</b>	3 shifts on 5.5 weekdays, 280 working days x 24h = 6700 yearly working hours; approx. 30 % preparation and servicing time, approx. 70 % production =>4700 production hours of the printing presses
<b>Products</b>	approx. 18000 t/yr commercial printings from approx. 20000 t/yr paper input and 500 t/yr ink input
<b>Dampening solution</b>	Approx. 1025 t/yr; consisting of 950 tonnes water, 50 tonnes IPA and 25 tonnes other additives
<b>Cleaning</b>	Approx. 15 t/yr (80 % for interim cleaning, 20 % for basic cleaning) and 100000-wipes.

**Table: Production conditions of the virtual heatset offset plant**  
[18, UBA Germany, 2003]

The following mass balance in Tabel below is calculated for the virtual plant described in **Error! Reference source not found.** and **Error! Reference source not found.**

INPUT	Amount	Unit	Notes	OUTPUT Products	Amount	Unit	Notes
				Commercial printings	18000	t/yr	Paper and ink
<b>Material</b>				Waste			
<b>Printing substrate</b>	20000	t/yr		Paper/misprints	2800	t/yr	
<b>Printing inks</b>	500	t/yr	Mineral oil concentration in ink 35 %, of which 85—90 % evaporates in the drier [38, TWG, 2004]	Ink residues	6	t/yr	Ink waste and in cleaning wipes, no VOCs
<b>Dampening solution</b>	950	t/yr	Without VOC				
<b>IPA</b>	50	t/yr	100 % VOC	Dampening solution residues	2	t/yr	4 % VOC
<b>Dampening solution additives</b>	25	t/yr	5 % VOC				
<b>Cleaning agents</b>	15	t/yr	80 % VOC free for interim cleaning, 20 % for basic cleaning	Mixture of cleaning agents and water	23	t/yr	50 % high boiling solvents

Cleaning wipes	100000	Items/yr	Usually reusable wipes, weight approx. 40 g/item	Cleaning wipes	100000	Items/yr	Containing 1 t ink and 3 t cleaning agents with 100 % VOC, of which 50 % evaporates fugitively
VOC total	203	t/yr		VOC in waste	2	t/yr	In-wipes, cleaning agents and waste dampening solution
Energy				Exhaust gas			
Energy in total	27100	MWh/yr		Volume flow	67.7 x 10 <sup>6</sup>	m <sup>3</sup> /yr	10 mg VOC/m <sup>3</sup>
Gas energy	13700	MWh/yr	t	VOC in purified gas	1.3	t/yr	
Electric energy	13400	MWh/yr		NO <sub>x</sub> in purified gas	2.7	t/yr	40 mg NO <sub>x</sub> /m <sup>3</sup>
Of which: Printing press	8900	MWh/yr		CO in purified gas	3.4	t/yr	50 mg CO/m <sup>3</sup>
Cooling	1700	MWh/yr		Fugitive			
Waste gas treatment	700	MWh/yr		VOC fugitive	47	t/yr	23 %

**Table: Input and output of the virtual heatset plant [18, UBA Germany, 2003]**

The VOC balance of the virtual plant is shown in **Error! Reference source not found.**

**Figure: VOC balance of the virtual plant [18, UBA Germany, 2003]**

However, it should be noted that **Error! Reference source not found.** [38, TWG, 2004]:

- shows that IPA VOC content is assumed to be 100 %, although it may contain up to 15 % water
- shows that in heatset printing, two large (32 page) fast presses, working three shifts during 280 days per year are needed to exceed a consumption of 200 t/yr. Most heatset plants have either two 8 page presses or one 8 page and two 16 page presses. Two 32 page presses in one plant is rare.

Heatset plants bigger than this virtual plant can be composed of several printing units which are similar to the virtual plant, although more and more plants are equipped with presses of differing web widths. The specific consumption and emission data can then be taken from this virtual plant. However, the specific consumption and emission values are significantly dependent on the manufactured products and will increase with [38, TWG, 2004]:

- decreasing print volume
- rising employment of special colours or change of colour sequence
- extremely high demands on the printing quality, or difficult printing images
- decreasing paper quality.

Several theoretical mass balances have been calculated from the virtual plant. Average VOC consumptions and emissions in relation to one tonne of ink used are shown in **Error! Reference source not found.**. Average input of material and output of waste of the virtual plant are shown in **Error! Reference source not found.**. However, these values are average values, which can—dependent on the above mentioned parameters—vary in practice by more than +/- 10 % [38, TWG, 2004].

**Error! Reference source not found.** shows that of 400 kg VOC input, 308 kg is captured and treated by thermal oxidation, so 92 kg are fugitive, which equals 23 % of the VOC input. After treatment, 3 kg of VOC are still in the waste gas and emitted and the efficiency of the waste gas treatment is 99 %.

**Figure: Specific VOC consumption and emission levels in a virtual heatset process**  
[18, UBA Germany, 2003]

**Figure: : Specific input of substances and output of waste in a virtual heatset process**  
[18, UBA Germany, 2003]

A study has been carried in Flanders (Belgium) and the Netherlands in 2003 on nine plants using over 200 t/yr VOCs [65, Intergraf, 2005]. From these, and further experiments, two types of press were identified, those capable of printing with low concentrations of IPA in the dampening solution (new or upgraded presses) and those not capable (existing plants). By trials to optimise the presses, two types of printing jobs were also identified: those that could readily run with low IPA concentrations (favourable), and 'difficult' ones that needed higher IPA concentrations, see **Error! Reference source not found.** 'Difficult' jobs involve all or some of the following:

- changes in the surface of the paper requiring numerous fine changes to settings of the press
- situations of high ink coverage where IPA prevents the occurrence of white spots
- lower levels of skill, education and experience of operators
- new, wide fast presses were also reported to need higher IPA to meet the demands of running wide plates, wide rollers with small amounts of sag, etc. [126, Verspoor, 2006]

Press type	Characteristics of the jobs to be printed	
Type 1: capable of using low IPA concentration	Favourable (A)	Difficult (B)
Type 2: not capable of using low IPA concentration	Favourable (A)	Difficult (B)

**Table: Combinations of heatset press and job type analysed**  
[65, Intergraf, 2005]

Consumption figures have been derived from the data collected by the Belgian study for dampening solution and cleaning agent consumptions, see **Error! Reference source not found.**

Situation	IPA or substitute	Cleaning agents	
Press type 1, type A jobs	2 % of ink weight	Mainly K3 (55–100 °C)	2 % of ink weight
Press type 1, type B jobs	10 % of ink weight	Mainly K3 (55–100 °C)	5 % of ink weight
Press type 2, type A jobs	5 % of ink weight	Mainly K3 (55–100 °C)	5 % of ink weight
Press type 2, type B jobs	15 % of ink weight	Mainly K3 (55–100 °C)	10 % of ink weight

**Table: Solvent consumption data for heatset press and job type**  
[65, Intergraf, 2005]

Virtual plant calculations have been made in **Error! Reference source not found.**, assuming the minimum possible consumptions of IPA, IPA substitutes and cleaning agents. For illustrative purposes, an ink consumption of 500 t/yr is assumed.

Emission sources	Press 1 jobs A	Press 1 jobs B	Press 2 jobs A	Press 2 jobs B
ink t/yr	500	500	500	500
VOC evaporating from ink %	35 %	35 %	35 %	35 %
VOC evaporating from ink t/yr	175	175	175	175
Emission from ink %	1.5 %	1.5 %	1.5 %	1.5 %
<b>Emissions from ink t/yr</b>	<b>2.6</b>	<b>2.6</b>	<b>2.6</b>	<b>2.6</b>
IPA or VOC in substitute % of ink weight	2 %	10 %	5 %	15 %
IPA or VOC in substitute t/yr	10.0	50.0	25.0	75.0
Fugitive IPA or VOC in substitute %	90 %	90 %	90 %	90 %
<b>Fugitive IPA or VOC in substitute t/yr</b>	<b>9.0</b>	<b>45.0</b>	<b>22.5</b>	<b>67.5</b>
Cleaning agents (CA) % of ink weight	2 %	5 %	5 %	10 %
VOC in CA %	100 %	100 %	100 %	100 %
VOC in CA t/yr	10.0	25.0	25.0	50.0
Emission factor CA	23 %	23 %	23 %	23 %
<b>Emissions from CA t/yr</b>	<b>2.3</b>	<b>5.8</b>	<b>5.8</b>	<b>11.5</b>
Total input t/yr	195	250	225	300
Total emissions t/yr	13.9	53.4	30.9	81.6
<b>% of ink weight</b>	<b>2.8 %</b>	<b>10.7 %</b>	<b>6.2 %</b>	<b>16.3 %</b>
<b>% of input (IED)</b>	<b>7.1 %</b>	<b>21.4 %</b>	<b>13.7 %</b>	<b>27.2 %</b>

**Table: : Heatset virtual plant VOC emissions**  
[65, Intergraf, 2005]

### 11.3.1 Consumption

[78, TWG, 2005], [155, TWG, 2016] [148, COM.,. 2009]

#### 11.3.1.1 Raw materials and additives

##### Printing inks

The basic constituents of offset inks are: pigments, binders (resins, varnish, mineral oil), and additives (drying substances). In addition, certain substances (printing oils/thinner, rub resistance pastes, gloss agents, drying retarders, etc.) are added to the inks to adjust their properties [8, Nordic Council of Ministers, 1998].

In heatset, there are only four standard colours. The inks are mainly organic and only a few inorganic pigments are used. The most commonly used are:

- black: carbon black
- inorganic: titanium dioxide, aluminium hydroxide, iron blue
- organic: diarylide yellows, lithol rubine 4B, phthalocyanine blue.

Phthalocyanine blue contains a strongly complex bound copper. Normal pigments can contain heavy metals in the form of small impurities in amounts counted in parts per million [8, Nordic Council of Ministers, 1998].

A typical formulation of heatset inks is shown in **Error! Reference source not found.**

Component	Contents	Concentration (wt %)
Binding agent	Resins, vegetable oils, mineral oils (b.p. 240–300 °C)	60–85
Colourants	Nearly exclusive organic pigments	10–25
Colour auxiliary agents	Siccatives (metal soaps), anti-oxidising agents (e.g. butyl hydroxyl toluene, hydroquinone), anti-skinning agents (e.g. cyclohexanone oxime), complex formers (e.g. EDTA, tartrates)	<10

**Table:: Typical basic recipe for heatset web offset printing inks**  
 [18, UBA Germany, 2003],[54, BMLFUW Austria, 2003] [78, TWG, 2005]

The total consumption of heatset inks in the EU 15 is estimated at 125 to 140 kilotonnes per year [4, Intergraf and EGF, 1999]. Data from the virtual heatset offset plant show a consumption of ink of 27.8 kg per tonne of finished product, or 25 kg per tonne gross (including wastage) [18, UBA Germany, 2003]. Experience of three plants over five years showed a consumption of 19 kg per tonne gross [38, TWG, 2004]. For the whole Finnish printing industry, the average ink consumption was 20.6 kg per tonne product [8, Nordic Council of Ministers, 1998]. A typical ink consumption is about 19 to 25 kg per tonne of output.

### Dampening solutions

[78, TWG, 2005]

Undiluted IPA is added to the dampening solution, unless they are replaced by tensides. In heatset offset, the concentration of IPA varies between 0–5–15 % depending on print job [4, Intergraf and EGF, 1999] [38, TWG, 2004].

Some older presses are designed to operate with concentrations of up to 30 % IPA or ethanol, and others with none. The concentration of IPA can be 30–50 % over the amount needed, without disturbing the printing process. On the other hand, having too little IPA immediately has a negative effect on the quality [4, Intergraf and EGF, 1999].

Sometimes concentrations of 2–8 % of IPA are used in combination with an additive, usually glycol ethers which are added to the dampening solution in concentrations of about 1 %. In some cases, working without IPA can be possible [8, Nordic Council of Ministers, 1998] [4, Intergraf and EGF, 1999].

**Error! Reference source not found.** shows the variation in IPA concentrations that are used, because of variations in presses and printing jobs.

In Germany, the implementation of the Solvent Emissions Directive has led to concentrations of IPA in heatset processes being limited to a maximum of 8 % [18, UBA Germany, 2003, 38, TWG, 2004].

Solvent consumption data for heatset press and job type data from 2003 are given in **Error! Reference source not found.**

An inventory in the German heatset printing industry showing the amount of IPA used (before 1999) was in the range of 18–21 wt % (in relationship to the total ink input being 100 %). However, more recent data show a ratio of 10 % in combination with 5 % of other additives from one virtual heatset offset plant. In 2002 in that virtual plant, (see **Error! Reference source not found.** and **Error! Reference source not found.**) the IPA input is 50 tonnes for printing 20000 tonnes printing substrate. The IPA concentration in the dampening solution is approx. 5 %. 18000 tonnes commercial printing products are produced and the input of IPA is then 2.8 kg per tonne of product and 100 kg per tonne ink used (10 %) [18, UBA Germany, 2003].

Ranges in IPA concentrations of 5–20 % are also reported to be common practice in Austria. [54, BMLFUW Austria, 2003].



Of 16 heatset printing plants in Flanders, Belgium, the range of IPA in relation to the ink input by weight, is from 0–47 %. In the three plants where no IPA is used, alternatives are applied. Relative to the ink input, two plants each with over 500 employees show IPA consumptions of 56 % and 176 % respectively [13, Aminal, et al., 2002].

In waterless printing processes, no dampening solution is applied and rejection of the ink in the non-image areas is being achieved by a silicone coating [4, Intergraf and EGF, 1999] [38, TWG, 2004].

### Varnishes

No data submitted.

### Cleaning agents

[4, Intergraf and EGF, 1999] [78, TWG, 2005]

Typical cleaning agents used for offset blankets and ink rollers are shown in **Error! Reference source not found.**

The solvent mixtures generally contain aliphatic, cyclical and/or naphthenic hydrocarbons. These are usually free of aromatic compounds for health and safety reasons. However, aromatic hydrocarbons, such as toluene, xylene, and halogenated solvents have been used [8, Nordie Council of Ministers, 1998] [4, Intergraf and EGF, 1999].

For the heatset processes in the EU 15, this is estimated at 13 kilotonnes per year, which is about 10 % of the ink input by weight. [4, Intergraf and EGF, 1999]. However, a range of 4.5–6.5 wt % has also been reported [18, UBA Germany, 2003]. Data from 16 heatset printing plants in Flanders, Belgium, report a range from 0.5–11.2 % based on the ink consumption, and one plant even reports a specific use of 110 wt % [13, Aminal, et al., 2002].

Where in the past very volatile and, in some cases, halogenated solvents were used for cleaning offset presses, there is a definite trend towards using less volatile solvents. This trend results in a substantial decrease of the VOC emissions from cleaning agents, but, on the other hand, increases the amount of hazardous waste. The increase in waste is, however, smaller than the decrease in VOC emissions. Experience shows that, once low volatility cleaning agents have been used for some time, the amount used can be decreased [4, Intergraf and EGF, 1999].

Nowadays, the proportion of cleaning agents used in heatset, sheetfed and generally in offset processes, is shown in **Error! Reference source not found.**

Cleaning agent	Heatset (1999)	Heatset (2000)	Sheetfed (2000)	Offset (2000)
	<b>Proportion (%)</b>			
Solvent mixtures with a flashpoint <21 °C	12.9	9	21	12–33
Solvent mixtures with a flashpoint of 21–55 °C	36.3	3	8.5	
Solvent mixtures with a flashpoint of 56–100 °C	39.2	76	68.5	61–79
High boilers with a flashpoint >100 °C	9.7	12	2	6–8.6
Vegetable oil esters with a flashpoint >150 °C	1.9			
Note				
Column 2 are data from German industry				
Columns 3 and 4 are data from Flemish industry				
Column 5 are data from Dutch industry and [38, TWG, 2004]				

**Table: : Cleaning agents in heatset and offset processes in general**  
[18, UBA Germany, 2003] [13, Aminal, et al., 2002]

In heatset processes in Austria, 90 % of the cleaning agents used are organic solvents with a vapour pressure >0.01 kPa. Of this amount, 70 % is used for intermediate cleaning which takes about 20–80 seconds and (for a 4 blanket to blanket units press, 96.5 cm wide) less than 1 litre cleaning solvent. Automatic cleaning of the press between two printing jobs takes about 0.5 l/hr (for a 4 colour double print press, 96.5 cm wide) [54, BMLFUW Austria, 2003] [38, TWG, 2004].

Solvent consumption data for heatset press and job type data from 2003 are given in **Error! Reference source not found.**

Automatic cleaning systems use some 10 % less cleaning agent than the amount needed when cleaning is manually carried out [4, Intergraf and EGF, 1999].

Some vegetable cleaning agents contain up to 15 % solvents. However, they are also available without [4, Intergraf and EGF, 1999] [38, TWG, 2004].

Some old presses may have molleton covered dampening rollers, although these are obsolete in the EU 15. These need to be removed from the press for cleaning. Solvents are not needed to clean these rollers, because they can be adequately cleaned using high pressure water sprays, occasionally helped with a small amount of detergent [4, Intergraf and EGF, 1999].

The VOC-relevant raw materials and additives are as follows:

### 1. Inks

Inks are based on about 33–35 % aliphatic hydrocarbons (solvents). The solvents are made of mineral oil. They are not volatile at ambient temperatures but are volatile in the dryer. About 85 % of the oil fraction is evaporated in the dryer as VOCs (equivalent to about 30 % of the total ink amount). Solvent residue in the finished product is not considered part of fugitive emissions because it is not volatile at ambient temperatures.

One tonne of ink allows the printing of about 330 000 m<sup>2</sup> (both sides) or 100 000 catalogues (48 pages DIN A4).

### 2. Dampening solution

Dampening solution consists mainly of water. It generally contains about 3 % dissolved salts and from 0 % up to 20 % isopropanol (isopropyl alcohol or IPA). Less commonly, dampening solution can contain ethanol instead of isopropanol. At 20 °C, isopropanol has a vapour pressure of about 4 kPa and ethanol of about 5.9 kPa. Both are therefore classified as VOCs.

It is considered good practice to minimise the isopropanol addition into the dampening solution.

### 3. Other additives

Other additives, based on less volatile or non-volatile organic compounds (often glycols), have been used to reduce the isopropanol content of dampening solution. The VOC content of these additives can vary from 0 % up to 30 %. The dosage is about 3 %, resulting in a final concentration of 0–1 % VOCs in the dampening solution.

### 4. Cleaning agents

Cleaning agents are mainly based on hydrocarbons. Aromatic hydrocarbons have good cleaning properties but their use has been restricted for health protection reasons. Common cleaners are mainly aliphatic hydrocarbons with vapour pressures of 0.1–11 kPa at 20 °C (100 % VOCs, flashpoints of 30–80 °C). Aromatic hydrocarbons are contained although to a lesser extent. Oily cleaning products, introduced in the 1990s, are based on natural oils, high-boiling mineral oils or mixtures thereof (0 % VOCs, vapour pressure < 0.01 kPa at 20 °C, flashpoint > 100 °C).

### 11.3.1.2 Energy [and resources]

[78, TWG, 2005]

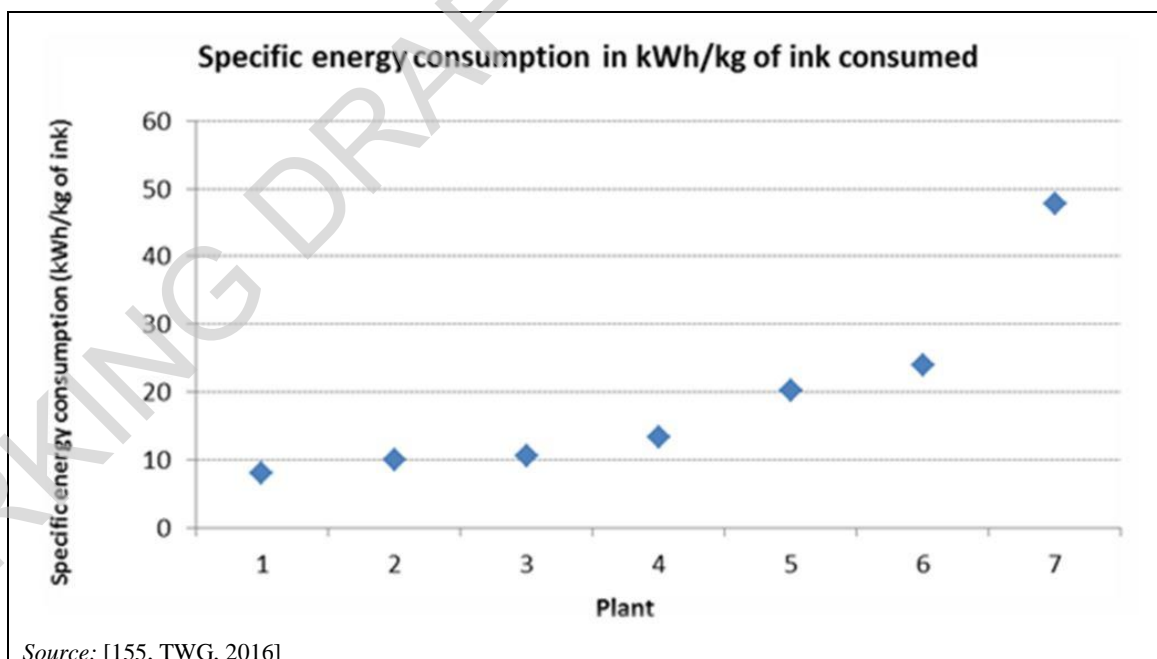
Energy consumption of the virtual heatset plant described in ~~Error! Reference source not found.~~ and ~~Error! Reference source not found.~~ are shown in ~~Error! Reference source not found.~~ and ~~Error! Reference source not found.~~. Energy consumption per tonne of ink is very variable on type of press, job and ink, etc. and not a realistic indicator [38, TWG, 2004].

Energy consumption heatset offset process	Consumption	Consumption
Total	1.355 MWh/t	54.2 MWh/t ink input
Gas	0.685 MWh/t	
Electricity	0.67 MWh/t	
Gas in waste gas treatment	4.60/t VOC in waste gas	
	15.56 GJ gas/t VOC	
	0.3 t LNG/t VOC	

**Table: Energy consumption in virtual heatset plant (from Table)**  
[18, UBA Germany, 2003]

**Figure: Specific energy consumption in a virtual heatset process**  
[18, UBA Germany, 2003]

The reported values for specific energy consumption expressed in kWh per kg of consumed ink are presented in Figure 11.1.



Source: [155, TWG, 2016]

**Figure 11.1: Reported values of specific energy consumption (kWh per kg of consumed ink)**

All installations reported heat recovery from the thermal waste gas treatment and reduced air ventilation at idle operation or maintenance. Other widely used energy-saving techniques are: air extraction and energy recovery from drying processes, central waste gas treatment with variable frequency drives, speed-controlled electric motors and air seals at dryer ovens.

Information from one installation on the energy-saving projects (techniques) that it applies or is in the process of implementing is presented in Table 11.1.

**Table 11.1: Energy-saving projects implemented by a heatset offset installation**

Technique title	Brief description	Economic elements
Lighting	2 000 lamps, optimised reflectors, one tube instead of two, all with dimmers: 60 % energy savings	15-month payback period of investment
Paper extraction	Paper extraction optimisation - frequency controlled motors. New motors and new equipment results to higher production security	Economic benefit: EUR 30 000/y
Printing plates	Printing plates exchanged: no preheating necessary	Economic benefit: EUR 25 000/y
Compressed air	Compressed air is stopped if machines are stopped more than 1 min	Economic benefit: EUR 3 500–4 000/machine per year; payback period < 1 year
Heat exchange for dryers	Use of heat of waste gases from the CHP gas turbine in the dryers of printing machines	NI
Air conditioning	Use of heat of waste gases from the CHP gas turbine for the room heating	NI
Compressed air	Compressed air system leakage measurement once every month.	NI

NB: NI = No information.  
 Source: [155, TWG, 2016] #148

**11.3.1.3 Printing substrates and other consumption**

[78, TWG, 2005]

*[TWG please provide updated information]*

**Printing substrates**

The substrate used in heatset is typically paper with a specific weight of the paper between 40–60 g/m<sup>2</sup>. Often coated LWC grades and uncoated paper are used with a specific weight normally of between 45–70 g/m<sup>2</sup>.

**Other consumption**

Other inputs are materials such as wipes for cleaning, containers and other packaging materials.

In heatset, four standard colours are used and these are supplied in reusable containers, which are either intermediate bulk containers (IBC) with a content of approximately 1 tonne, or common 200 litre metal drums [4, Intergraf and EGF, 1999].

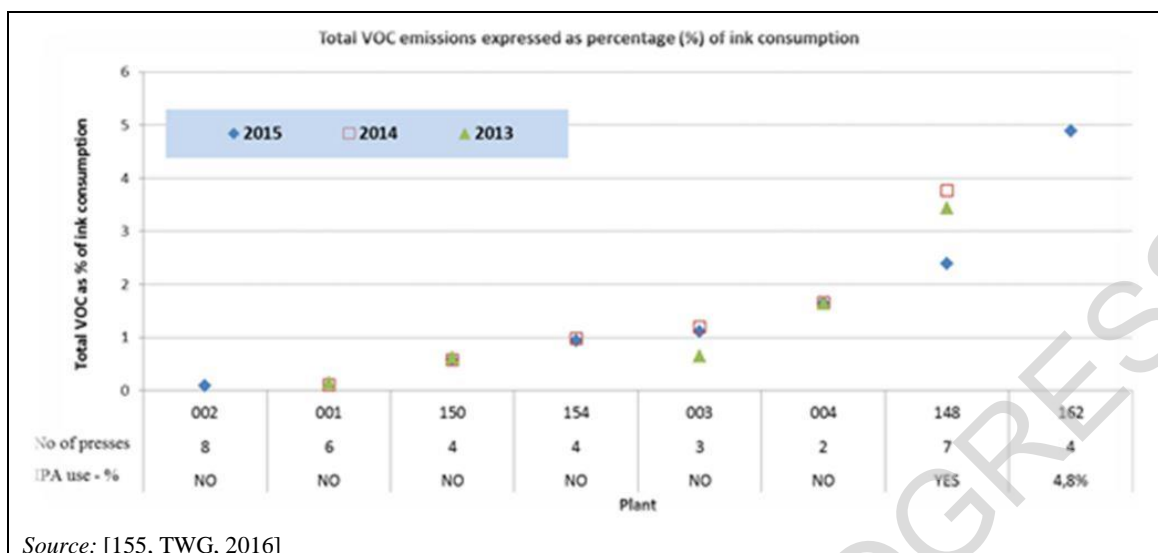
Wipes are usually reusable and weigh about 40 grams. A heatset printing plant reported using about six wipes per tonne printed product, which equals 200 wipes per tonne ink used [4, Intergraf and EGF, 1999, 18, UBA Germany, 2003, 38, TWG, 2004].

**11.3.2 Emissions**

**11.3.2.1 Total VOC emissions**

[155, TWG, 2016]

The reported values of total VOC emissions expressed as a percentage of the ink consumption are presented in Figure 11.2.



**Figure 11.2: Total VOC emissions (as a percentage of the ink consumption)**

In general, most of reported values are low and are related to installations where no isopropanol is used (full substitution of IPA). The higher values refer to installations where the dampening solution contains a small percentage of IPA. All installations use thermal waste gas treatment techniques which is the general rule in the sector due to the offensive smell of waste gases.

The reported total VOC emission values and relevant contextual information are presented in

Table 11.2.

**Table 11.2: Reported values of total VOC emissions and contextual information for heatset offset plants**

Plant number	IPA use	No of presses	Rubber blanket washing system	Inking roller washing system	Total VOC emissions (% of ink consumption)		
					2015	2014	2013
002	No	8	Auto tissue (8)	Auto tissue (8)	0.08	ND	ND
001	No	6	Auto brush (4)- manual (2)	Auto brush (2) Auto tissue (1) Manual (3)		0.11	0.15
150	No (from 2015)	4	NI	NI	0.58	0.58	0.62
154	No	4	NI	NI	0.94	0.98	
003	No	3	Auto brush (2) Auto tissue (1)	Manual (3)	1.11	1.19	0.65
004	No	2	Auto tissue (2)	Manual (1) Auto (1) (spray tube)	1.64	1.66	1.64
148	Yes	7	Auto tissue (7)	Auto (7)	2.39	3.77	3.44
162	4.8 %	4	Auto brush (3) Auto tissue (1)	NI	4.89	ND	ND

NB:

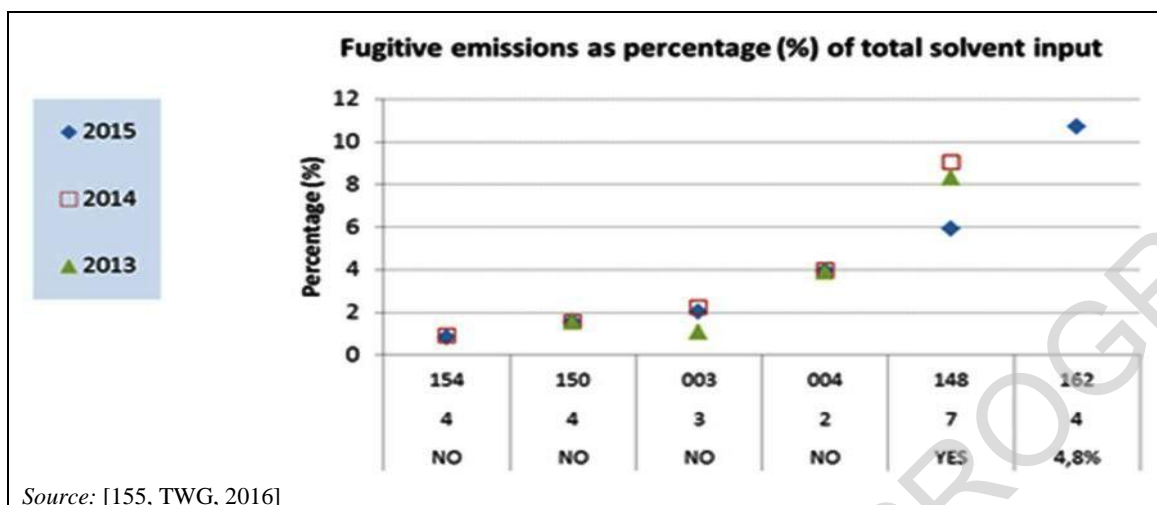
NI = No information.

ND = No data.

Source: 155, TWG, 2016

### 11.3.2.2 Fugitive VOC emissions

The reported values of fugitive VOC emissions expressed as a percentage of the total solvent input are presented in Figure 11.3.



Source: [155, TWG, 2016]

**Figure 11.3: Fugitive VOC emissions (as a percentage of the total solvent input)**

The reported values for fugitive emissions are significantly lower than the IED limit value (30 % of the total solvent input for both new and existing installations).

The main reported techniques applied to minimise fugitive emissions are as follows [155, TWG 2016]:

- Direct piping of inks: Inks are moved through a closed system from the storage area to the print basket. This was reported from all installations.
- Direct piping of printing additives from their original packaging to the printing basket.
- Direct piping of solvent from storage to the automatic washing systems.
- Use of small containers for solvents for manual cleaning.
- Air extraction for the drying processes. In one case, solvent-laden air from the drying zones is treated in a two-step solvent recovery unit from where solvents are recovered and returned to the ink producing company for reuse.
- Collecting panels after dryers to minimise emissions when paper web leaves the dryer.
- Air extraction from the cooling zone.
- Safe storage of hazardous substances and measures to prevent unplanned releases.

Techniques specifically used in heatset web offset to reduce VOC emissions are (see Section 11.4):

- Low-VOC additives for dampening solutions;
- optimising the IPA concentration in the dampening solutions;
- use of waterless offset plates;
- automatic cleaning systems for blanket cylinders;
- web offset dryer integrated with thermal WGT.

The total European unabated VOC emissions from heatset plants are estimated to be in the order of magnitude of 100 kilotonnes per year. Over half of these emissions stem from the IPA in the dampening solution and the rest from the cleaning agents. The emissions from the ink created in the drier are of high boiling oils and are abated, together with an estimated 10 % of both IPA

and cleaning agents that are also extracted via the drier where the driers extract air from the press room.

According to the RAINS model, at EU-25 level for 2000, NMVOC emissions from heatset were 40 kt representing 0.38 % of the total NMVOC emissions. The total activity was 123.59 kt with an average emission factor of 3239 g NMVOC/kg which shows this industry already reduces some emissions [79, EGTEI, 2005].

Some data show 50 % of the original VOC emissions will remain unabated [4, Intergraf and EGF, 1999]. Other data show that much lower levels of fugitive VOC emissions in the range of 25–30 % are achievable [54, BMLFUW Austria, 2003], with low IPA consumption and the use of low volatility cleaning agents. Even levels of around 23 % are reported to be achieved; see Table [38, TWG, 2004].

Fugitive emissions are described as a percentage of the input in the IED. In heatset printing, key techniques for reducing fugitive VOC emissions are the reduction of VOC solvent inputs. Expressing the emission as a percentage of the input therefore does not reflect the changes made. Reduction scheme calculations that overcome this problem are used in Germany and Austria, but not in the IED. A study has been carried out showing that for heatset it is more useful to express emissions as a percentage of the ink consumption [65, Intergraf, 2005]. See Annex 0.

The waste gases of heatset presses tend to smell offensively. In many cases, this was the original driving force for installing incinerators in this part of the printing industry [4, Intergraf and EGF, 1999].

In the following paragraphs details about the different emission sources are discussed.

### **Inks**

The total emission of solvents from heatset inks, that normally contain 30–35 % solvents in the EU-15, is approximately 45 kilotonnes. Of these solvents, 80–90 % evaporate in the drier and are usually treated [4, Intergraf and EGF, 1999, 38, TWG, 2004].

The ink is supplied in bulk and is transported directly to the presses by pumping it through a piping system. This is common practice in very large plants [4, Intergraf and EGF, 1999, 38, TWG, 2004] [78, TWG, 2005].

### **Dampening solution**

The IPA, or sometimes ethanol, added to the dampening solutions, will evaporate during the printing process; approximately 85–90 % is fugitive and approximately 10 % (in heatset) will be extracted through the driers and treated [4, Intergraf and EGF, 1999]. However, other sources report that 50 % of the dampening solution applied in heatset processes are captured and treated [54, BMLFUW Austria, 2003]. The amounts of IPA consumed are also partly emitted, and these are reported in Section 0.

IPA can be partially substituted by glycol ethers which also evaporate although to a lesser extent than the amount of IPA substituted. However, the ozone forming potential of some glycol ethers may be 10 times greater than that of IPA; the advantages need to be assessed on a weight for weight basis.

Waterless offset printing has no emissions to air from the dampening process [4, Intergraf and EGF, 1999, 38, TWG, 2004].

### **Cleaning agents**

Emissions of the estimated 100 kilotonnes of cleaning agents used in European offset plants are dependent on the sort of cleaning equipment, print job, solvent applied, etc. High or low boiling solvents show very different emission levels. The mass balance of the virtual heatset plant that

is shown in **Error! Reference source not found.**, shows an example of the percentage of solvents that can be emitted to air, partly via an incinerator and partly fugitively.

The percentage of solvent emissions that stem from automatic interim cleaning in heatset processes and that is captured and routed to the waste gas treatment are in the range of  $\leq 15$ –50 % [18, UBA Germany, 2003, 54, BMLFUW Austria, 2003].

Solvent emissions in heatset processes from cleaning by hand and basic cleaning, that are captured and routed to the waste gas treatment, are in the range of 0–5 %.

### Capture

The average VOC concentration in the waste gases from heatset processes is in the range of 1–3 g/Nm<sup>3</sup> due to the absence of any recirculation of drier air. The waste gases smell so offensively that recirculation would give the printed product an unacceptable smell. The absence of recirculation encourages a proportionately large airflow and incinerator capacity. The low concentration causes a relatively high energy demand [4, Intergraf and EGF, 1999, 18, UBA Germany, 2003]. However, data from a good practice press in Austria (a 4 colour double-sided press which is 96.5 cm wide), extracting between 1000–4000 Nm<sup>3</sup> air, show a maximum VOC concentration of 8 g/Nm<sup>3</sup>. For comparison, this is nearly 50 % more than the two very large presses in the virtual plant in Table.

There are various waste gas treatment options, which are discussed in Section 17.11.

### Incineration

Incinerators can be integrated in the driers or can be a central system to which all driers are connected, see Section 17.10. In Austria (where VOC abatement was implemented early), 80 % of the central systems use regenerative incinerators [38, TWG, 2004].

The incineration temperature needs to be 750–800 °C. The calorific value of the waste gases may not be enough to attain this temperature unaided [4, Intergraf and EGF, 1999]. However, under the best conditions it can be an autothermic process where regenerative incineration is used [18, UBA Germany, 2003, 38, TWG, 2004].

The three incineration techniques applied in heatset plants show the characteristics as shown in **Error! Reference source not found.**

Emissions	Unit	Thermal	Catalytic	Regenerative
Total carbon of which methane	mg C/Nm <sup>3</sup>	<20	<50 some 25	<30
NO <sub>x</sub>	mg/Nm <sup>3</sup>	100	20	100
Energy		Thermal	Catalytic	Regenerative
Temperature	°C	750	400	800
Natural gas	m <sup>3</sup> /h	105	20	20
Exhaust temperature	°C	350	200	200
Electricity	kW	100	100	75
Heat loss	kW	2640	1400	1400

Table: Achievements of applied incineration techniques in heatset plants [4, Intergraf and EGF, 1999, 38, TWG, 2004]

Thermal oxidation can achieve slightly lower VOC emissions; the efficiency is better by some 0.1 %. This is, however, paid for by substantially higher energy consumption. The consumption in natural gas is five times that of the two other systems.

The thermal oxidation applied in the theoretical virtual plant described in Table has a VOC reduction efficiency of 99 % and shows the following emission levels. However, this is associated with a very high combustion temperature of 900 °C compared to a more usual 750–800 °C [18, UBA Germany, 2003] [38, TWG, 2004]:



- 19 mg VOC/m<sup>3</sup>
- 40 mg NO<sub>x</sub>/m<sup>3</sup>
- 50 mg CO/m<sup>3</sup>.

**Condensation**

Condensation normally has an efficiency level of around 90 % [52, SPIN Netherlands, 1994]. However, it will not meet emission values required by the IED and is not often used [38, TWG, 2004].

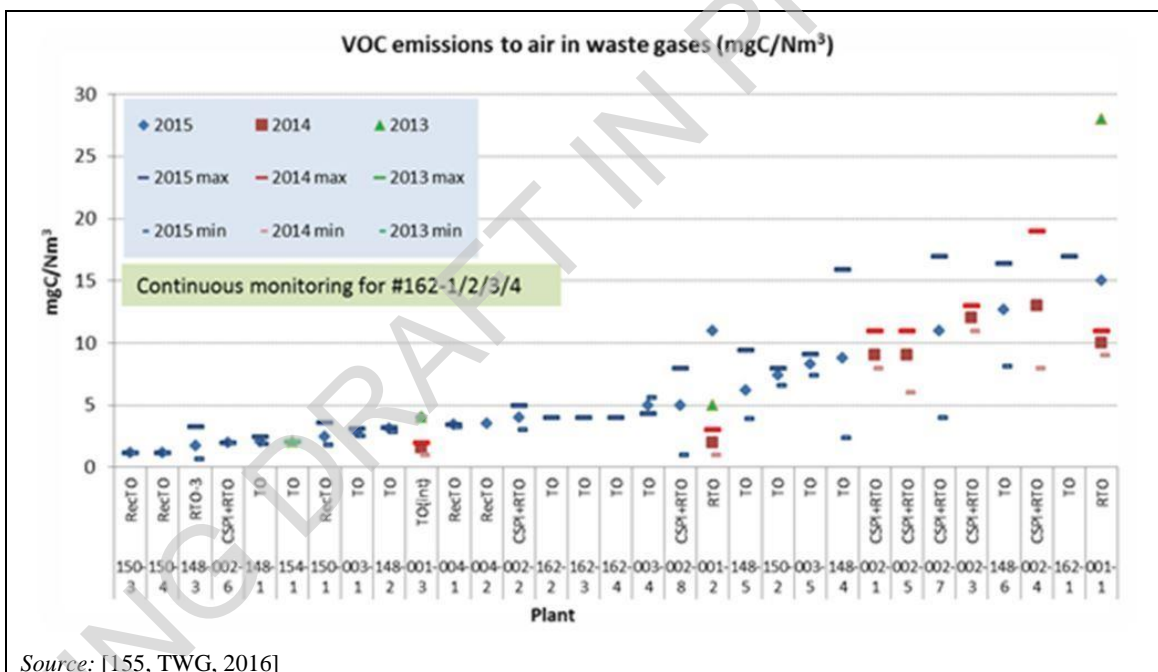
**Biological treatment**

Reported as not being successfully used in this industry. See Section 17.10.7.

**11.3.2.3 Emissions to air in waste gases**

**11.3.2.3.1 VOC emissions to air in waste gases**

The reported values for VOC emissions to air in waste gases, expressed in mg C/Nm<sup>3</sup>, are presented in Figure 11.4.



Source: [155, TWG, 2016]

**Figure 11.4: VOC emissions to air in waste gases (mg C/Nm<sup>3</sup>)**

The monitoring frequency varies from twice a year up to once every three years.

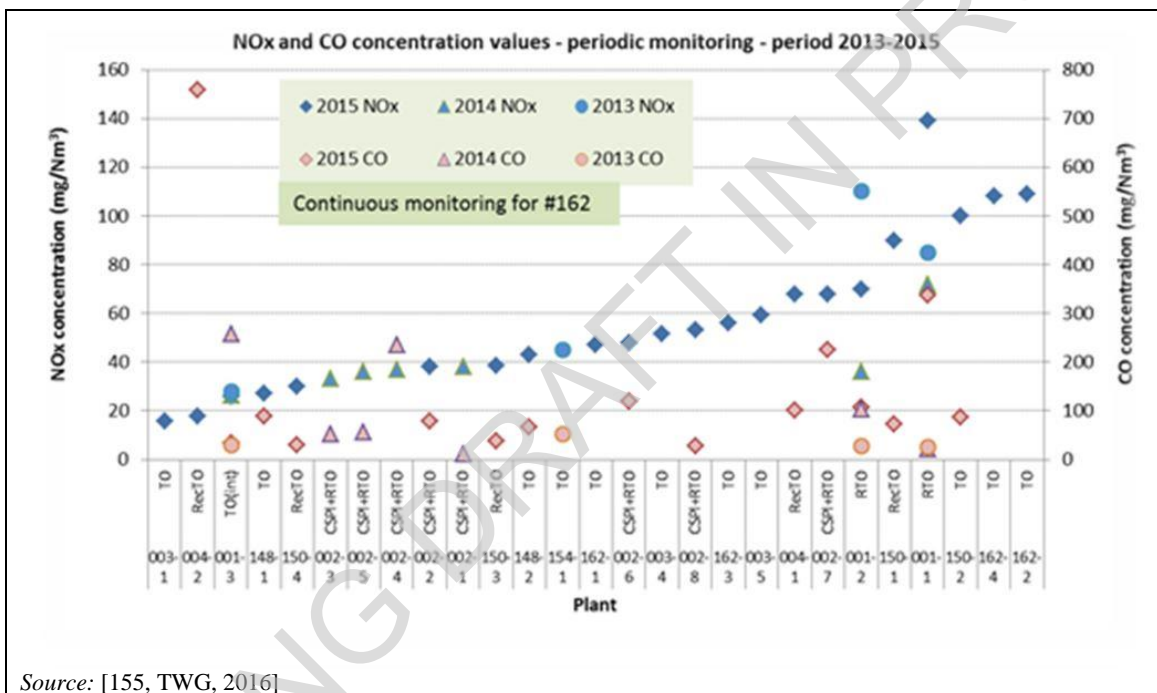
The basic statistical parameters of reported data are presented in Table 11.3.

Table 11.3: Statistical parameters of reported values for VOC emissions to air in waste gases

Year/parameter	No of values	Average	75 <sup>th</sup> percentile	Median	25 <sup>th</sup> percentile	
2015	Average	22	5.5	8.1	4	2.6
	Max.	18	6.5	8.9	4	3.1
	Min.	18	3.3	4	2.7	1.8
2014	Average	7	8.1	11	9	5.5
	Max.	7	10	12	11	7
	Min.	7	6.3	8.5	8	3.5
2013	Average	4	9.8	-	-	-
	Max.	1	-	-	-	-
	Min.	1	-	-	-	-

11.3.2.3.2 Nitrogen oxides (NO<sub>x</sub>) and carbon monoxide (CO) emissions

The reported values for periodic monitoring of NO<sub>x</sub> and CO emissions to air in waste gases are presented in Figure 11.5.



Source: [155, TWG, 2016]

Figure 11.5: NO<sub>x</sub> and CO emissions to air in waste gases for the period 2013–2015.

The monitoring frequency varies from twice a year up to once every three years.

The basic statistical parameters of reported data are presented in Table 11.4.

**Table 11.4: Statistical parameters of reported values for NO<sub>x</sub> and CO emissions to air in waste gases**

Year / parameter		No of values		Average		75 <sup>th</sup> percentile		Median		25 <sup>th</sup> percentile	
		NO <sub>x</sub>	CO	NO <sub>x</sub>	CO	NO <sub>x</sub>	CO	NO <sub>x</sub>	CO	NO <sub>x</sub>	CO
2015	Average	22	15	59	145	70	113	52	86	38	52
	Max.	18	11	64	121	84	128	57	90	40	56
	Min.	14	11	44	50	49	67	38	61	34	30
2014	Average	7	7	40	105	ND	ND	36	56	ND	ND
	Max.	7	7	44	133	ND	ND	37	74	ND	ND
	Min.	7	7	37	65	ND	ND	33	36	ND	ND
2013	Average	4	4	67	33	ND	ND	ND	ND	ND	ND
	Max.	1	1	ND	ND	ND	ND	ND	ND	ND	ND
	Min.	1	1	ND	ND	ND	ND	ND	ND	ND	ND

NB: ND = No data.  
Source: 155, TWG, 2016

**11.3.2.3.3 Dust emissions**

Only a small number of installations reported values for periodic monitoring of dust emissions to air in waste gases. Dust emissions are mainly related to the paper trimmer and in some cases extracted gases from this process are treated using dry particle filters. In general, reported dust emission values are very low and vary from 0.2 mg/Nm<sup>3</sup> up to 0.8 mg/Nm<sup>3</sup>.

**11.3.2.3.4 Waste**

[78, TWG, 2005] [155, TWG, 2016]

**Papers**

The amount of waste paper produced in heatset offset is usually higher than in other printing methods, as a significant amount of paper is used before a proper balance between ink and dampening water is achieved and a good print quality is produced.

The reported proportion of paper waste in the overall quantity of substrate is about 15 % [155, TWG 2016]

~~The virtual heatset plant described in Section 0 produced 2800 tonnes of waste for 20000 tonnes of substrate, which is equal to a waste of 14 % of the input paper substrate [18, UBA Germany, 2003].~~

Waterless offset is claimed to produce less waste, as there is no balance between ink and dampening to be achieved.

Waste paper is delivered to a specialised recycling company off site. In the case of medium- (offcuts) and high-quality (white) waste paper, a direct delivery to the paper mill was reported.

**Inks**

~~The virtual heatset plant described in Section 0 produced 12 kg ink waste per tonne ink used, of which 10 kg are left over inks and 2 kg are inks absorbed into cleaning wipes [18, UBA Germany, 2003].~~

Reported values show that the quantity of produced ink waste varies from 2 kg up to 6.5 kg per tonne of used ink.

**Dampening solution**

During printing, the dampening solution can become contaminated with paper dust and small amounts of ink. These solutions contain AOX and small amounts of metals. Normally, these

waste dampening solutions are delivered to a waste recycling company. ~~discharged, and may require pretreatment described in detail in Section 11.3.2.4 [4, Intergraf and EGF, 1999] [18, UBA Germany, 2003, 38, TWG, 2004].~~

### Cleaning agent

Large amounts of used cleaning agents may arise, especially in large printing plants where most of the cleaning is done automatically. The estimated amount is some 100 kilotonnes cleaning agents per year in the EU-wide offset printing industry, which is disposed of [4, Intergraf and EGF, 1999] [38, TWG, 2004].

~~The virtual heatset plant described in Section 0 generated 46 litres waste water with 50 % high-boiling solvents for each tonne of ink used [18, UBA Germany, 2003].~~

Cleaning agents are reused to a great extent and the disposal of these solvents as hazardous waste may be reduced by some 50 % [4, Intergraf and EGF, 1999].

### Wipes

Wipes from cleaning the press contain organic solvents, ink and sometimes varnish. The amount usually varies with run length, and therefore number of changeovers per year. ~~The virtual heatset plant described in Error! Reference source not found. and Error! Reference source not found. used approximately 200 pieces solvent wipes per tonne ink used, contaminated with an average of 10 g ink and 30 g cleaning agent each [18, UBA Germany, 2003] [38, TWG, 2004].~~

### Other wastes

Old printing plates contain metals, primarily aluminium, with traces of other metals, depending on the age of the equipment. Blankets are also discarded. Waste can also contain filters from filtering the dampening solution and discarded UV lamps from the platemaking process. [8, Nordic Council of Ministers, 1998] [38, TWG, 2004].

Standard colours of offset inks can be supplied in reusable IBC containers or in the common 200 litre metal drums.

## 11.3.2.4 Waste water

### Dampening solutions

During printing, the dampening solution gets contaminated with paper dust and small amounts of ink. These solutions then contain AOX in concentrations of > 1 mg AOX/l and small amounts of metals such as aluminium, copper, zinc, cobalt and manganese (these last two from drying agents), all together in concentrations of around 0.1 g/l. Normally these waste dampening solutions are discharged, often after treatment [4, Intergraf and EGF, 1999] [18, UBA Germany, 2003].

The additives used in dampening solutions in concentrations of around 3 % may contain small amounts of biocides against algae. Common concentrations of biocides are in the range of 0.1–0.2 %, which means that the ultimate concentrations in the dampening solution are negligible [4, Intergraf and EGF, 1999].

Normally, printing plants are not equipped with a waste water treatment plant and discharge directly to the municipal sewerage system. Where discharges cannot be allowed because of excessive levels of contaminations, disposal as hazardous waste is an alternative [4, Intergraf and EGF, 1999].

### Cleaning agents

The effluent from cleaning dampening rollers used in water-based printing processes contains hardly any contamination. It may contain some detergents, some substances that can be found in

the dampening solution and small amounts of ink. This effluent is normally not treated but discharged directly to the sewerage system [4, Intergraf and EGF, 1999].

A study by the TWG identified the main parameters and other substances of interest that may be discharged in waste waters (including those mentioned above) and therefore to be considered for the data collection<sup>26</sup>. For heatset printing, BPA and NP were identified as substances of interest; however, no data were received in the data collection.

## 11.4 Techniques to consider in the determination of BAT for the heatset offset printing

[78, TWG, 2005]

In Chapter 17, techniques are discussed which might also be applicable to the printing industry. In Table 11.5, the general techniques relevant for heatset offset printing are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

**Table 11.5: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### 11.4.1 Solvent mass balance for the heatset sector

[192, INTERGRAF, 2017] [202, UNECE, 2016] [205, BE, 2005]

*[Work in progress – TWG please provide additional information]*

#### Description

Method for determining the VOC emissions from heatset web offset and proving compliance with emission limit values for total of fugitive emissions

#### Technical description

This sector model for a heatset solvent mass balance provides a straightforward structure and method for determining the total and fugitive VOC emissions with sufficient accuracy.

<sup>26</sup> COM working document EIPPCB 09/06/2016: Assessment of Technical Working Group (TWG) data submitted on metals and other emissions to water for their consideration as Key Environmental Issues for installations carrying out IED Annex 1 6.7 activities

The relevant sources of emissions are identified as being the evaporation of VOCs used as additives in fountain solutions, VOCs used as components in cleaning agents in both automatic and manual cleaning of parts of the press and the end-of-pipe emissions, and the VOCs not destroyed in the waste gas treatment.

For each of the identified sources, emission factors and production parameters are defined. The emission factors are press- or plant-specific and can be calculated based on data known to the operator, such as press size and speed, VOC percentage in the product used, their vapour pressure, etc. It also provides a method to determine if and to what extent it may be assumed that VOC evaporation taking place in the press room or press encapsulation can be directed in by the dryers and destroyed.

The basic elements of the Heatset SMB are presented below:

### *Basic elements of the SMB at the heatset sector*

*Work in progress – TWG please provide additional information*

The scope is that the heatset sector SMB should be easily elaborated by every operator.

#### *Basic parameters:*

##### *Sources of emissions:*

1. VOCs in fountain solution. Evaporating from the ink and water rollers on its way from the fountain to the paper web.
2. VOC cleaning agents for in automatic blanket wash. Idem.
3. VOCs in other cleaning agents. Idem.
4. Non-oxidised VOCs in outlet waste treatment.
5. ....
6. ....

##### *Emission factors:*

- 1, 2 & 3: To be calculated using total surface of ink and water rollers, the percentage of VOCs in the fluid, the vapour pressure of the VOCs and the press speed while printing or cleaning (to represent the 'wind factor' that increases evaporation).
- 4 To be calculated on the basis of inlet and outlet concentrations and airflow.
- 5 & 6 .....

##### *Production parameters:*

Ad 1: production hours excluding make ready.

Ad 2 & 3: Number of cleaning operations.

##### *Other parameters*

.....

### **Achieved environmental benefits**

The heatset sector solvent mass balance (SMB) not only shows whether a heatset plant complies with its emission limits, but also where in the production process these emissions take place and why. If emission reductions are necessary, this sector mass balance is a management tool that shows where these reductions can be achieved most efficiently.

### **Environmental performance and operational data**

The SMB for heatset has been used to determine the emissions of well-performing plants. This SMB sector can therefore be regarded as the preferred measuring method for determining the total and fugitive emissions for heatset plants.

The heatset SMB is, like almost every mass balance, a simplification of the actual situation. Since the sector is reasonably homogenous, this method will work satisfactorily in most cases. Where an operator however employs machines or working methods differing from the industry standard, the SMB should be amended accordingly. Also where the operator has more detailed

knowledge and relevant data than the minimum necessary to elaborate the SMB for heatset, he should make use of these.

**Cross-media effects**

None.

**Technical considerations relevant to applicability**

This use of SMB for heatset is applicable in all or most heatset plants.

The method avoids the use of measured solvent concentrations and airflows in exhausted press room air. In these press rooms, other printing processes, such as coldset of sheetfed offset, may take place. These processes do not fall under the scope of the STS BREF, but they may cause VOC emissions. These emissions should not be allocated to the heatset process of the plant.

**Economics**

Making an SMB of sufficient accuracy is not an easy task. It takes time and effort to find and collect the necessary data. There is however a rapid learning curve. Once the plant-specific emission factors have been calculated and a reliable administrative system for the production parameters is working, the time spent on the SMB is minimised. Only when important changes take place, such as a change of materials used or the installation of a new press, must the emission factors be recalculated.

**Driving force for implementation**

Annex VII to the Directive 2010/75/EU (IED) and environmental permits.

**Example plants****Reference literature****[Conventional heatset inks]**

*Conventional techniques have been deleted if they can no longer be considered BAT.*

*This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumption or emissions*

**Description:** ~~The basic constituents of offset inks are: pigments, binders (resins, varnish, mineral oil), and additives (drying substances). In addition, certain substances (printing oils/thinner, rub resistance pastes, gloss agents, drying retarders, etc.) are added to the inks to adjust their properties. The binder content of the inks (high boiling petroleum fractions and vegetable oils) used in heatset web offset printing processes is about 25 to 50 %.~~

**Achieved environmental benefits:** ~~The solvent part of these inks is high boiling and is part evaporated in the driers.~~

**Cross-media effects:** ~~Contain mineral oils from non-renewable sources.~~

**Operational data:** ~~See Section 0.~~

**Applicability:** ~~No information submitted.~~

**Economics:** ~~No information submitted.~~

**Driving forces for implementation:** ~~No information submitted.~~

**Example plants:** ~~No information submitted.~~

**Reference literature:** [4, Intergraf and EGF, 1999]

#### 11.4.2 Material-based techniques [Replacement of conventional heatset inks **(substitution)**]

##### **Inks based on vegetable oils**

*Proposed for deletion as not applicable in heatset web offset – TWG please confirm*

##### **Description**

~~Inks based on vegetable oils, such as soy bean oil, can sometimes replace the mineral oils in conventional ink.~~

##### **Achieved environmental benefits**

~~Reduced VOC emissions and worker exposure compared to petroleum based oils  
The main advantage is that Vegetable inks are made from renewable sources and the sludge generated when de-inking printed matter will be more biodegradable.~~

~~Cleaning can be done with water and detergents.~~

~~It is common to regard the mineral oil free inks as cleaner technology, although a full lifecycle assessment is not known. These inks are preferred to mineral oil based inks according to the Nordic Swan labelling criteria.~~

##### **Cross-media effects**

~~Vegetable inks have a tendency to adhere strongly to the fibres with the result that they make de-inking difficult.~~

~~Due to the inevitable petroleum content, ink waste may still be hazardous.~~

##### **Operational data**

~~Vegetable oil inks result in less ink build up; show greater stability and increased flexibility.  
The drying process for soy based inks is considerably slower, particularly on coated paper.  
Thus, pure soy based inks cannot be used in the heatset process. As a result, soy based oils still contain a certain percentage of petroleum. In addition poor drying can result in set off, marking and poor rub resistance.~~

~~In heatset processes, these inks are not commonly used, see Applicability, below.~~

##### **Applicability**

~~This technique is not applied in heatset offset, where the mineral oils are evaporated, as the vegetable oils do not evaporate fast enough. They are only used in sheetfed offset, where the oils do not evaporate but harden through oxidation. Vegetable based inks and varnishes are not applicable to printing newspapers.~~

##### **Economics**

~~No information provided.~~

~~No capital cost; ink cost can be 5%–8% higher compared to~~

##### **Driving force for implementation**

~~No information provided.~~

##### **Example plants**

~~No information provided.~~

##### **Reference literature**



[8, Nordic Council of Ministers, 1998] [11, IMPEL, 2000] [18, US EPA et al., 2003] [38, TWG, 2004], [2006, PNEAC, 2017]

#### 11.4.2.1 Reducing emissions from the dampening solution

It must be noted that where percentages of IPA are discussed, it is not always clear whether per cent by volume or by weight is intended. The difference is important enough to be taken into consideration [38, TWG, 2004].

In addition to technical press requirements, a number of issues significantly affect the possibility of reducing or completely substituting IPA:

- Changes in the surface of the printed paper (different kinds of coating, absence of coating, different degrees of calendering, etc.) require changes in numerous fine settings of the press. These changes take press-time and increase the amount of paper lost in make ready. Where IPA is used, such changes in paper surface can be dealt with faster and with less paper loss than where IPA has been reduced or substituted. Where frequent changes in paper surface occur, reduction or substitution of IPA may have a serious negative economic effect.
- In situations of high ink coverage (the percentage of the surface that actually carries ink), the use of IPA makes it possible to allow very small areas to remain without ink. In situations of full ink coverage, the use of IPA better prevents the occurrence of small water droplets that cause white spots in fully printed surfaces. Where frequently high ink coverage or full ink coverage needs to be printed, reducing or substituting IPA may thus result in a substantial increase of intermediate cleaning of the blanket cylinder and plate.
- Where skill, education and experience of press operators is not of a very high level, failure of any experiment toward reducing or substituting IPA is almost unavoidable. Equally, an experienced operator may significantly reduce the chances of successful IPA reduction, by maintaining traditional approaches.

See also general techniques for substitution, Section 17.7.2.

#### **Replacement of IPA in the dampening solution (substitution)**

*This technique has been replaced by: Low VOC additives for dampening solutions (Low Isopropanol (IPA) concentration or IPA-free wetting agents in fountain solutions) (see Section*

##### **Description**

~~Additives exist which allow lower IPA concentrations in the dampening system. Most of these additives are glycol ethers. They are added in concentrations of about 1 %, or sometimes 3–5 %, depending on the additive, to the dampening solution. Some additives are intended to totally replace IPA, others are meant for use in combinations with low concentrations of IPA. Ethanol is sometimes used to replace IPA as a seemingly ‘eco-solvent’ (see Cross media effects, below).~~

Additives that give good results and have low ozone forming potential (see Section 17.6.2) are:

- ~~propylene glycol;~~
- ~~glycerol;~~
- ~~di hydro 3 methyl 2.5 furandion;~~
- ~~butyldiglycol.~~

##### **Achieved environmental benefits**

~~IPA concentrations of 2–8 % (actual figures depend on the measurement method used) are achievable, and in some cases working without IPA becomes possible. Glycol ethers also evaporate and represent VOC emissions, but emissions will be less than that of the substituted IPA. However, this might not help in the purpose of reducing VOC emissions with the aim of preventing ozone formation. The ozone forming potential of some glycol ethers may be 10 times higher than that of IPA if the same amount evaporates.~~

### **Cross-media effects**

Some additives were suspected to have serious health and safety consequences, but they are believed not to be on the market currently. Safety data sheets should, therefore, be studied before using the additive. However, it must be pointed out that the additives listed above all have a substantially lower occupational exposure limits than isopropanol.

These additives should only be used where it is clear that evaporation is lower than in the case of isopropanol.

Sometimes ethanol is used for replacing IPA; however, this should be avoided because the ozone forming potential of ethanol is twice as high as IPA. This, in combination with a vapour pressure that is a third higher than that of IPA, will only have a negative environmental effect.

### **Operational data**

The reduction in IPA consumption is not automatically the result of substitution. The specifications for the products to be printed, the combination of paper ink, the local climate, and the ability of the press room personnel very much determine whether substitution has the desired effect.

Using ceramic, chromium plated or hydrophilic distributing rollers in combination with hydrophilic plate rollers assists the partial use of replacements for IPA, see Section **Error!**

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### **Applicability**

Applicable to all heatset offset printing plants.

### **Economics**

Costs for IPA are EUR 0.55 per litre, and costs for the substitute is about EUR 1–1.50 per litre. Because the quantity of additives needed to replace IPA is less, the overall costs are the same. However, changing over to another technology always involves costs because of loss of production at the time of change.

### **Driving force for implementation**

Solvent Emissions Directive. Health and safety: roughly 90 % of the IPA evaporates through the press and never reaches the paper, requiring a high level of ventilation.

### **Example plants**

Impress Group, Lint, Antwerp, Belgium (IPA substituted completely).

### **Reference literature**

[4, Intergraf and EGF, 1999] [8, Nordic Council of Ministers, 1998] [14, Aminimal, et al., 2002] [12, Netherland, 1996] [38, TWG, 2004] [78, TWG, 2005]

#### **11.4.2.1.1 Use of low or IPA-free additives for dampening solution**

[186, INTERGRAF, 2017]

### **Description**

Reduction or avoidance of Isopropanol (IPA) use as a wetting agent in heatset dampening (fountain) solution, through substitution by mixtures of other organic compounds which are non-VOC and/or VOC of a lower volatility.

### **Technical description**

To attain a print of acceptable quality in offset, it is necessary to fully wet all the hydrophilic parts of the plate, but with a minimal thickness of the water layer of approximately 2 µm. This needs to be a stabile process, even where the press speed varies. A wetting agent is therefore

necessary. The wetting agent reduces the surface tension of water and thus minimises the amount of water necessary for a perfect coverage of the hydrophilic parts of the plate.

The fountain solution also needs other additives such as acids to control the pH, plate conditioners to avoid corrosion and Arabic gum to further protect the offset plate are also necessary. These other additives are not discussed here

Traditionally, the most commonly used wetting agent is Isopropanol (IPA). IPA is not only a good wetting agent, it is also 'forgiving' in the sense that imperfections in both press and paper web and changes in speed do not quickly lead to an interruption in the tightly controlled wetting process and the resulting immediate and severe problems with print quality. In the past, IPA was frequently employed in the fountain solutions in concentrations of 15% w/w and more.

Where high volatility VOCs like IPA are used as a wetting agent, a considerable part evaporates on its way to the plate and the rubber blanket and thus becomes a fugitive emission. The remaining part is absorbed by the paper web, quickly transported to the dryer, evaporated there and destroyed in the oxidiser. In general terms, the lower the volatility of the wetting agents, the lower the proportion that evaporates fugitively and the lower the starting concentration needs to be. Also other VOC's may not be as easily released from water as IPA is.

On today's presses, with well-trained operators, good maintenance and adequate quality control it is often possible to substitute the IPA to a large extent or even completely by additives containing organic compounds that are non-VOC or VOCs of a lower volatility. Wetting agents that are fully non-VOC may not be expected. On modern presses, in particularly demanding circumstances, reduction of IPA concentration in the dampening solution to 3% w/w can be achieved. On older presses it should be possible to reduce the IPA concentration to 5% w/w.

In all cases the dampening solution must be cooled to approximately 10 to 15C to reduce the evaporation en route to the plate.

#### **Achieved environmental benefits**

Significant reduction of solvents' evaporation from fountain solutions, resulting in a considerable reduction of fugitive emissions from the fountain solution

#### **Environmental performance and operational data**

Compared to a situation with an IPA concentration of 15% w/w the fugitive emissions from fountain solutions are reduced by some 80%.

#### **Cross-media effects**

Where the use of IPA in the fountain solution is avoided, there is a need to use biocides to prevent the growth of algae and other micro-organisms in the dampening system. The biocide is however transported by the paper web to the oxidiser together with the other additives in the fountain solution.

Where occasionally a small amount of fountain solutions needs to be disposed of, this should be done as special waste mainly because of this biocide content.

#### **Technical considerations relevant to applicability**

May be limited by technical, training and quality requirements:

The water film brought onto the offset plate must be very thin (0.5 to 1 g/m<sup>2</sup> or 0.5 to 1 µm). Where the film is too thin, it breaks and parts of the plate 'run dry'. Where the film is too thick it is not removed adequately from the hydrophilic parts of the plate. In both cases the result is an unrecognisably coloured and smudged paper web.

In order to reduce the IPA consumption and to apply additives containing non-VOC's or low volatility VOC's, the press must be properly equipped with for example ceramic, metal or hydrophilic distribution and plate rollers (see Section 11.4.2.1.3). The rollers must be adjusted with precision and the press must be well maintained. Temperature control is essential.

The required state of the press and operator training for successful reduction of the IPA to maximum 3% w/w does not differ largely from what is necessary to apply only non-VOC and low-VOC additives to the fountain solution.

In some cases, the complete avoidance of the use IPA may have qualitative drawbacks. The use of substitutes increases the amount of water that needs to be brought onto the plate for adequate wetting by 30 to 50% compared to the situation where IPA is the sole wetting agent. This unavoidably reduces the sharpness of the printed dots because of the less than perfect separation of the ink-water emulsion on the plate. As a result, there are limits to the achievable quality when printing without IPA, even on modern presses with well-trained operators, good maintenance and adequate quality control.

In spite of the above, in most cases the print quality is still fit for purpose, but where these quality issues occur, this may become apparent in for example images with lots of detail (human faces, woodgrain), with large variation in lighting of objects, very dark unsaturated colours or subtle grey balances. As a result, the use of isopropanol may be required for certain products that need a better than normal printing quality. Examples of these products are museum art catalogues and high quality annual reports.

### **Economics**

A learning curve applies to both the achievement of a low IPA concentration and the application non-VOC or low-VOC additives. During the learning curve production is down because of lower press speeds and quality problems. It takes several years to achieve the situation where under all circumstances a low IPA concentration can be maintained or the use of IPA can completely be avoided.

In the long run a saving on the consumption of wetting agents is attained and also a saving occurs due to the avoidance of costs associated with the flammable properties of IPA.

No specification of the cost and savings is available.

### **Driving force for Implementation**

IPA use is generally reduced for reasons both of worker exposure and to reduce fugitive emissions.

### **Example plants**

All plants that have submitted data

### **Reference literature**

[155, TWG 2017]

- VDI-richtlinie VDI 2587: Emission control web offset presses (November 2002) (section 2.1.1.4)
- Reducing VOC solvent use in the Printing Industry: (A.M.McCourt, Printing Industries Association Of Australia, 1999)
- Printing and the environment: Intergraf (1999)
- Paper interaction with fountain solution during multi-color offset printing (F.Ciolacu & Elene Bobu, Pulp, paper and printing department "GH.Asachi" Technical University of Iasi, Romania)
- Fountain solution in lithographic offset printing (April 2011, Sameer S.Deshpande, Govt. Polytechnic, Beed, Maharashtra, India)

#### **11.4.2.1.2 Optimising the concentration of IPA in the dampening solution**

##### **Description**

Optimise the IPA concentration in the dampening by adjusting water hardness and pH, continuous measurement of the IPA concentration, and using specific inks and/or plates

##### **Technical description**

The IPA concentration in the dampening solution is reduced as far as practically possible. There are several factors:

- more diligence is necessary for the adjustment of the printing press;

- to achieve reproducible printing conditions at a reduced IPA concentration, an exact and continuous measurement of the IPA concentration is needed, e.g. by infrared or ultrasound measuring systems;
- to assist with printing at low IPA concentrations, adapted inks are used, which are capable of taking up more water than normal heatset inks;
- offset plates with adapted coating are capable of being covered with more water than normal heatset plates, while still not humidifying the ink-carrying parts of the plate;
- exact adjustment of the water hardness and the pH value, and just monitoring the water quality, is a prerequisite for achieving an IPA concentration as low as possible.

#### **Achieved environmental benefits**

In heatset offset, the concentration of IPA varies typically between 8–15 %. This means that for existing webfed presses an average reduction of 26 % can be achieved. For new and newly designed webfed presses this is 65 %.

#### **Cross-media effects**

None.

#### **Operational data**

Measuring IPA concentrations exactly is difficult. The automatic IPA measuring devices on most presses are usually of simple designs, influenced by temperature and the presence of other additives. However, under comparable circumstances, they give comparable results, so they can be used for quality control purposes, even though they do not always correctly indicate the exact IPA concentration. It is not necessary to use sophisticated measuring devices to be able to reduce IPA consumption to a minimum.

#### **Applicability**

All heatset offset printing plants applying IPA.

#### **Economics**

Costs of a continuous IR measurement system was EUR 70000 – 100000 per press in Finland in 2002.

#### **Driving force for implementation**

Although the IED does not prescribe a maximum % IPA, it does limit fugitive emissions from heatset, and in order to attain that limit, every effort should be made to reduce the IPA concentration in the dampening solution.

In Germany the concentration of IPA in heatset processes is limited to a maximum of 8 %.

#### **Example plants**

No information provided.

#### **Reference literature**

[4, Intergraf and EGF, 1999, 18, UBA Germany, 2003] [12, Netherland, 1996, 38, TWG, 2004]

##### **11.4.2.1.3 Ceramic, metal and hydrophilic distribution and plate rollers**

This technique is related to the use of Low-VOC additives for the dampening solutions (see Section 11.4.2.1.1).

#### **Description**

Applying a ceramic, chromium-plated or hydrophilic distributing roller in combination with hydrophilic plate rollers. Hydrophilic plate rollers are made of soft rubber. These rollers can form a particularly thin and unbroken dampening film on the plate roller with lower IPA concentrations.

These rollers are also successfully applied in situations where IPA is partly substituted.

### **Achieved environmental benefits**

Lower VOC emissions as IPA concentrations can be reduced by 2–3 %, depending on the starting concentration.

### **Cross-media effects**

Soft rubber is damaged sooner than plate rollers made of hard rubber and needs to be replaced more often, resulting in more waste. Also, ceramic rollers need to be replaced more frequently than chromium-plated steel ones.

### **Operational data**

Whether ceramic or chromium-plated distributing rollers give better results, depends on the type of press. Ceramic rollers require more maintenance and cleaning time.

In one offset plant in Norway where IPA is partly substituted, the level of IPA could be reduced from 15 % to 4 %, which resulted in a reduction of the IPA concentration in the air above the press in the range 77–90 %.

### **Applicability**

This technique is commonly applied and is applicable in all printing plants applying IPA. However, ceramic or metal rollers are now used less. Hydrophilic rollers are used, have the same effect, and are cheaper.

### **Economics**

The costs for hydrophilic plate rollers are the same as for hard rubber rollers and vary from EUR 250–1 000 each. However, they need to be replaced more often. Ceramic rollers cost EUR 2 500–3 000 each. The total costs of replacing distributing rollers for ceramic ones depend on the size of the press. Also ceramic rollers need to be replaced more frequently than chromium-plated ones (costs are from approximately 1997).

### **Driving force for implementation**

No data submitted.

### **Example plants**

Norwegian plant.

### **Reference literature**

[14, Aminal, et al., 2002] [4, Intergraf and EGF, 1999] [8, Nordic Council of Ministers, 1998, 38, TWG, 2004]

### **Exact adjustment of the inking rollers**

*Proposed for deletion as it is a commonly applied process in the sector*

#### **Description**

~~Perfect adjustment in the relative position of the rollers and the plate cylinder allows for lower IPA concentrations. Minute maladjustments are a cause for ruptures in the water film. The addition of IPA makes the dampening solution less sensitive to this phenomenon.~~

#### **Achieved environmental benefits**

~~Enables low IPA concentrations to be used.~~

#### **Cross-media effects**

~~No information provided.~~

#### **Operational data**

~~No information provided.~~

**Applicability**

New presses are generally equipped for exact adjustment of rollers. Retrofitting is not possible.

**Economics**

No information provided.

**Driving force for implementation**

No information provided.

**Example plants**

No information provided.

**Reference literature**

[65, Intergraf, 2005] [78, TWG, 2005]

**Apply a spray system in the dampening unit**

*Proposed for deletion as it is not applied in the sector*

**Description**

~~In a spray dampening system, the nozzles used to spray the dampening solution have an oscillating motion which makes the dampening solution feed more linear compared to conventional systems, such as the roller system.~~

**Achieved environmental benefits**

~~Spraying, instead of applying the solution by a roller system, requires lower concentrations of IPA.~~

**Cross-media effects**

None.

**Operational data**

No data submitted.

**Applicability**

~~This technique does not allow an exact dosage of very thin water film and therefore is not applicable to heatset.~~

~~This technique is used in newspaper printing (coldset) where more water is used because it helps to remove paper dust. In newspaper printing, no IPA or very low IPA concentrations are achieved. This is only possible because these very thin water films are not necessary since there rarely is a very high ink coverage and the paper can easily absorb all excess. It does not transfer to heatset offset.~~

**Economics**

No information provided.

**Driving force for implementation**

~~IED, H&S and economic reasons (automation of press operation requires the ability to make very fine adjustments).~~

**Example plants**

No information provided.

**Reference literature**

[8, Nordic Council of Ministers, 1998] [38, TWG, 2004]

## **Cooling the dampening solution**

*Proposed for deletion as it is a commonly applied process in the sector*

### **Description**

The circulation and dosing systems for dampening solutions containing IPA are cooled to about 8–15 °C to reduce the evaporation of IPA.

### **Achieved environmental benefits**

Two thirds of the IPA input is already evaporated before it reaches the dampening rollers and the printing plate. At the time the dampening solution reaches the printing plate, the IPA concentration is only about 1 %. Cooling the solution reduces the evaporation rate.

The concentration on the plate is very difficult to measure due to the very thin ink film. The information about the remaining IPA concentration on the plate is disputed in the Intergraf EWP. The conclusion was reached in the late 1980s through model calculations.

### **Cross-media effects**

Cooling requires energy.

### **Operational data**

Most presses are equipped with a cooling system as standard.

### **Applicability**

Commonly applied to heatset offset printing plants.

### **Economics**

No information provided.

### **Driving force for implementation**

No information provided.

### **Example plants**

No information provided.

### **Reference literature**

[14, Aminal, et al., 2002, 38, TWG, 2004] [78, TWG, 2005]

## **Cooling the dampening rollers and plate cylinders**

*Proposed for deletion as it is not applied in the sector*

### **Description**

Cooling the dampening rollers and plate cylinders reduces the temperature and evaporation of the applied dampening solution.

### **Achieved environmental benefits**

No information provided.

### **Cross-media effects**

No information provided.

### **Operational data**

Cooling temperatures are, for example:

- dampening rollers 28–29 °C;



- plate cylinders 28.5–32 °C.

**Applicability**

Retrofit not generally possible.

**Economics**

No information provided.

**Driving force for implementation**

No information provided.

**Example plants**

No information provided.

**Reference literature**

[78, TWG, 2005]

**Removal of IPA solutions from the dampening unit**

*Proposed for deletion as it is not applied in the sector*

**Description**

Removing dampening solution from the dampening system during press stops, such as overnight and during weekends. Automatic systems are available.

**Achieved environmental benefits**

Some reduction in IPA emissions.

**Cross-media effects**

No information provided.

**Operational data**

Nowadays, in most plants, the IPA solution is continuously circulated by pumping in an amount greater than the press uses. The excess is piped back to the reservoir, where IPA additions are made. The technique cannot be usefully applied where presses are run 24 hours per day, which is generally the case in heatset plants exceeding the thresholds in Annex I (6.7) to the IPPC Directive.

**Applicability**

Applicable to heatset offset plants.

**Economics**

No information provided.

**Driving force for implementation**

No information provided.

**Example plants**

No information provided.

**Reference literature**

[14, Aminal, et al., 2002] [4, Intergraf and EGF, 1999] [11, IMPEL, 2000] [38, TWG, 2004] [78, TWG, 2005]

**Filtering the dampening solution**

*Proposed for deletion as it is a commonly applied process in the sector*

**Description**

The dampening solution is continuously recirculated. A filtering unit can prolong the lifetime for the dampening solution. Where other substances are substituted for IPA, the water becomes contaminated more quickly and filtering during recirculating reduces water consumption and the production of waste (which may be hazardous).

**Achieved environmental benefits**

Less water is consumed and so less is discharged as waste water.

**Cross-media effects**

Filtering requires energy.

**Operational data**

No information provided.

**Applicability**

Applicable to all heatset offset printing plants running at low IPA concentrations.

**Economics**

No information provided.

**Driving force for implementation**

No information provided.

**Example plants**

No information provided.

**Reference literature**

[8, Nordic Council of Ministers, 1998, 38, TWG, 2004] [78, TWG, 2005]

**Controlling the hardness of the water for the dampening solution**

*Proposed for deletion as it is a commonly applied process in the sector*

**Description**

Dampening solutions are centrally prepared, monitored, cooled and filtered, and supplied to all presses in the plant. The hardness of water is a regional variable, which influences the quality of the dampening solution and its emulsification degree in the ink. Treating the raw water by demineralisation and hardness balancing (remineralisation to a predetermined level) makes it easier to define how much additive is needed and improves the quality of the dampening solution.

The treatment can be by ion exchange and/or reverse osmosis. For example, the calcium content of the raw water can be reduced by reverse osmosis and the hardness adjusted to the optimal value, about 70–140 ppm as CaCO<sub>3</sub>.

**Achieved environmental benefits**

A more accurate dosing of additives, including IPA, is possible, and cooling and filtering are more efficient. This leads to less use of energy, less waste water and loss of raw materials due to a lower amount of misprints. If IPA is applied, it will lead to less emissions of IPA to air. However, in a centralised system, the IPA concentration (or any other substitute) will be adjusted to the press that needs the highest concentration.

**Cross-media effects**

~~Demineralising water requires energy and chemicals. Reverse osmosis requires energy.~~

**Operational data**

~~No information provided.~~

**Applicability**

~~This technique is applied in large heatset offset plants but may not be beneficial where the water is of a suitable constant composition.~~

**Economics**

~~Installation of this technique in new plants or in plants where a few new presses are installed, is not very expensive. Costs for retrofit are high.~~

**Driving force for implementation**

~~An automatic system allows better quality control, as well as better control of IPA consumption.~~

**Example plants**

~~No information provided.~~

**Reference literature**

~~[14, Aminal, et al., 2002] [8, Nordic Council of Ministers, 1998, 38, TWG, 2004]~~

**11.4.2.2 Waterless offset**

[192, INTERGRAF, 2017]

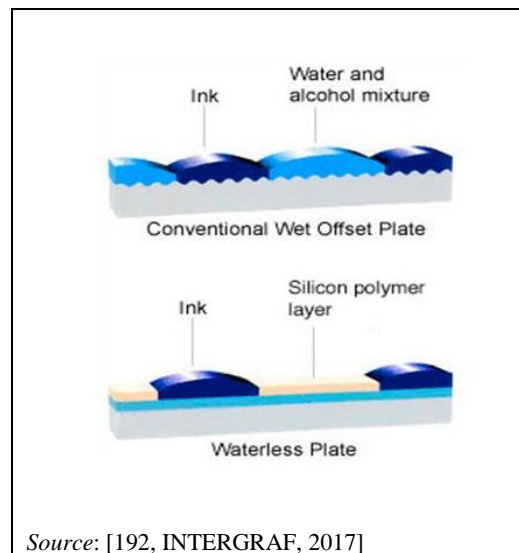
**Description**

Use of a specific coating on the plates eliminating the need for IPA.

**Technical description**

On special offset plates a layer of silicones is laser hardened on the non-ink carrying parts or alternatively hardened silicones are burnt away to produce ink carrying areas. The hardened silicones have the same effect as the fountain solution on traditional offset plates: they locally keep the plate clear of ink (see Figure 11.6). There is only one manufacturer world-wide.

The application of waterless offset requires considerable changes to the printing process, additional cooling of the press, and the use of special inks.



**Figure 11.6: Conventional wet offset plate and waterless plate**

~~Waterless offset is an offset printing technique that does not use water/oil separation to ensure that the ink only covers the image carrying parts of the plate: separation is achieved by special plates and inks. In normal offset, the plate is hydrophobic in the image carrying places and hydrophilic elsewhere. Water is used to make sure that the oily inks do not attach to the non-image carrying parts. In waterless offset, the non image carrying parts have a coating that achieves the same effect. No water is needed.~~

#### **Achieved environmental benefits**

Since no fountain solution is used, there is also no need for any additives such as isopropanol or other wetting agents and there are therefore no fugitive emissions from those additives. In addition there is less paper loss during make-ready.

~~No dampening solution is required, eliminating any emissions from this source, particularly IPA. There is a saving of raw materials (paper and ink), however, these advantages may disappear if additional cleaning is required for longer runs in heatset.~~

#### **Environmental performance and operational data**

Torray plates do not last long. Where traditional offset plates can be treated in order to last long enough for longer runs, the plates for waterless plates need to be replaced during such a long run. This results in the production of additional plates and more frequent make ready and paper losses. The cost of these significantly reduce the economic advantages of waterless offset. This is also the reason why waterless offset is more often encountered in sheetfed offset than in web fed offset.

~~The technique has some distinct advantages over 'normal' offset. Its printing quality is better and 'make ready' is faster. The process runs smoothly.~~

#### **Cross-media effects**

Additional energy consumption for cooling the press. The plates cannot be as easily recycled as conventional offset plates.

~~As there is no dampening solution, waterless offset requires additional ways to carry off heat from a printing unit and the additional cooling consumes energy. However, no energy is required for the dampening solution.~~

~~Ink temperature control systems are used as standard in waterless offset presses. Other additional temperature control systems can be suitable means for better stabilising and~~

controlling the temperature in waterless offset printing. Control systems include: separate ductor roller temperature control systems, multizone temperature control systems, plate cylinder temperature control systems, rubber blanket cylinder temperature control systems and oil cooling and/or bearing cooling systems.

### Technical considerations relevant to applicability

The application of waterless offset requires considerable changes to the printing process, additional cooling of the press, and the use of special inks.

The special plates need to be replaced after considerably fewer prints than traditional offset plates, making the technique less applicable for long print runs such as usual in IED sized heatset plants

Application of waterless offset reduces the flexibility of the printing plant. Pre-press activities by the customer may need to be adapted. The process is for example reported to have difficulty printing large areas of black ink, which may need to be circumvented by using all four colours instead.

On the other hand, in waterless offset, dot sharpness may improve and allow a somewhat sharper print quality.

It is applied for newspaper, magazines, brochures, flyers etc.

The technique is generally applicable for high quality full colour jobs and/or short runs: this is typically sheetfed work, although heatset runs are decreasing in length. The technique has been applied in heatset, see 'example plants', below.

For heatset presses, the following questions have been raised:

- The waterless process does not trap paper dust, therefore requiring higher quality paper and/or more cleaning. Against this, the paper is not wetted, as it is repeatedly in multiple passes for colour offset printing.
- The life of waterless plates is still not well established and is reported to be a maximum of 100 000 to 300 000 revolutions.
- Waterless plates are more sensitive to scratching, e.g. during cleaning operations.
- Waterless systems have a smaller number of rollers, limiting the ink quantity transferred and fine adjustments at the press. The suppliers claim that because no dampening solution is transferred, more ink can be transferred, and a new press has been installed with no ink keys.
- The range of ink colours has been limited although the spectrum may now be larger.

### Economics

To an existing installation, the investment is considerable since large changes have to be made to the presses.

On short runs the reduction in make-ready constitutes a saving. There are however additional cost for cooling the press and more expensive plates.

Presses, plates and the inks are more expensive than those used in 'normal' offset, however, there are no costs for isopropanol, water and dampening solutions and 'making ready' time is shorter implying less costs for paper and ink. However, longer runs may need more plates and cleaning operations.

### Driving force for implementation

The reduction of paper losses due to the shorter make-ready periods results in an economic advantage in the case of short runs.

In the past, the lack of operator exposure to Isopropanol vapours was also considered an advantage, but this no longer applies due to the drastic reduction of Isopropanol usage in the industry.

Achieves very high quality work. Reduction in chemicals usage improves workplace health and safety.

### Example plants

See [www.waterless.org](http://www.waterless.org), the website of the International Waterless Printing Association

Toppan printing, Hokuseisha, Seikousha, Aika, GAO, Kousolu offset, Sanesu (all these plants are in Japan). In Europe, there are many sheetfed presses, 25 newspaper presses and about five waterless heatset presses: Quebecor, UK; two are in Switzerland (one retrofitted a dampening unit in 2003) and two in Hungary (both were moved from Germany).

### Reference literature

- Beste Beschikbare Technieken voor de grafische sector. Vlaams Kenniscentrum voor Beste Beschikbare Technieken (VITO) Juni 2013
- [www.waterless.org](http://www.waterless.org), the website of the International Waterless Printing Association

[4, Intergraf and EGF, 1999, 14, Aminimal, et al., 2002] [18, UBA Germany, 2003] [36, Hamann, 2004] [38, TWG, 2004] [78, TWG, 2005]

## 11.4.3 Waste gas collection and treatment

### 11.4.3.1 Treatment of air extracted from press room or press encapsulation ~~[Encapsulation of presses or extraction and treatment of air from the press room]~~

[192, INTERGRAF, 2017]

#### Description

The dryer takes its inlet air from the press room or the press encapsulation. As a result, a part of the solvents evaporated in the press room or encapsulation are abated. This reduces the fugitive emissions.

#### Technical description

Heatset presses are often encapsulated for reasons of climate control and noise reduction and, where necessary, to avoid excessive exposure of personnel to solvent vapours. A stable offset printing process needs a constant temperature and low velocity of the air streams around the press. The noisy parts of the printing process are the print rollers, the dryer and the folding and cutting machine. These are often placed in an encapsulation together with the press itself.

In other cases, encapsulation is not applied for technical or economic reasons. This may for instance be the case where flying imprint units are used. These necessitate numerous plate changes and operator presence at the running press. In these cases the press is not encapsulated but operated as much as possible from a separate control room.

Temperature controlled air is fed into the press room or the encapsulation. The inlet air for the dryer serves as a part of the exhaust air ventilation. A proportion of the air is thus not exhausted to the atmosphere, but to the dryer and the oxidiser. As a result, a part of the solvent vapours in the room or the encapsulation are treated. This reduces the fugitive emissions.

The airflow of modern dryers and integrated dryer/oxidisers is between 5.000 and 20.000 m<sup>3</sup>/h. The total airflow needed for controlling the climate inside the press room or the encapsulation

depends on factors such as the number, the size and the speed of the presses and is generally larger than the amount evacuated by the dryers. Additional exhaust ventilation to the atmosphere is needed. Due to the low solvent concentration in the additionally ventilated air, it is economically not viable this is not suitable for treatment.

The solvent concentration in the press room or encapsulation is low. The highest concentrations will be found where isopropanol is used as additive in the fountain solution. But even in those cases the concentration will, for health and safety reasons, be well below the occupational exposure limit for isopropanol (Germany MAK 200 mg/m<sup>3</sup>). As a result of this low concentration, to increase the dryer airflow such that it alone could provide enough exhaust ventilation for the encapsulation.

~~Heatset presses are sometimes encapsulated for reasons of temperature control, avoiding draughts and to reduce noise. IPA evaporates within the encapsulation. The air from the encapsulation is extracted by the dryer and may be sent to the incinerator, thus destroying all or most IPA emissions.~~

~~In some cases, where the presses are not encapsulated, the air in the press room is extracted and removes volatilised isopropanol and high volatility cleaning agents.~~

### **Achieved environmental benefit**

Reduction of fugitive emissions

~~Treating extracted air will reduce emissions of IPA and high volatility cleaning agents. Encapsulation reduces noise.~~

### **Environmental performance and operational data**

An approximate calculation for the proportion of the solvent vapours in the encapsulation that are treated is given by the following formula:

Airflow dryers (or integrated dryer-oxidiser)  
(Airflow dryers + additional exhaust ventilation)

~~The waste gas treatment systems are usually only designed for the airflow from the dryers. A modern dryer has a capacity of 4 000 – 7 000 m<sup>3</sup>/h; older ones up to 10 000 m<sup>3</sup>/h. In order to also extract the air from the presses, capacities of 50 000 m<sup>3</sup>/h or more are needed. The thermal treatment will need increasing in size and if the air contains less solvent, will also need support fuel.~~

### **Cross-media effects**

No negative environmental effects

~~Extraction fans increase energy consumption and may increase noise levels.~~

~~For reasons of health and safety, the concentration of IPA and other solvents usually have to be kept well below occupational exposure limits. This means that the solvent concentration will be far below 1 g/m<sup>3</sup> (OEL IPA: 650 mg/m<sup>3</sup> (reported by the Netherlands, 2001), most cleaning agents have far lower OELs). At this low VOC concentration in the inlet gas, the waste gas incineration cannot be autothermic, and substantial additional fuel is required. Costs and energy consumption to deal with the flows extracted from the presses do not outweigh the emission reduction that can be achieved (see Operational data, below).~~

### **Applicability**

Applicable in all Heatset plants

Inks from heatset do not evaporate at room temperature. They are evaporated in the dryer and therefore always captured. Where low volatility cleaning agents are used, they also evaporate in the dryer. Encapsulating the press with or without treating the press ventilation air has no effect on solvent emissions and it is carried for occupational health and safety reasons.

Encapsulation of the presses and routing the air to waste gas treatment is common practice in publication gravure (for more details see Sections 0 et al.). However, it is not practicable in heatset offset as the capacity of existing waste gas treatment systems may not be sufficient or may not be effectively used treating this air with very low VOC concentrations.

### Economics

No additional cost

See Cross media effects, above. To increase the size of an incinerator from say 5 000 m<sup>3</sup>/h to 50 000 m<sup>3</sup>/h, the additional investment will be some EUR 450 000. Electricity consumption for the main fan would increase accordingly and the fuel consumption would grow from negligible to substantial because autothermic operation would no longer be possible.

### Driving force for implementation

Ventilation of the press room or the encapsulation is necessary for reasons of climate control and to avoid excessive exposure of personnel to solvents. Taking the inlet air for the dryers from the press room or the encapsulation is aiding towards this ventilation.

Encapsulation of the presses is to reduce noise and other health and safety requirements. Press room air is always extracted for workplace health and safety.

### Example plants

All or almost all Heatset plants

Encapsulation is widely applied. Extraction is generally applied. Treatment of the press room air is not usual.

### Reference literature

[8, Nordic Council of Ministers, 1998] [14, Aminal, et al., 2002] [4, Intergraf and EGF, 1999, 38, TWG, 2004] [78, TWG, 2005]

No information provided

#### 11.4.3.2 ~~[Extraction and]~~ Treatment of air from the dryer

[192, INTERGRAF, 2017]

**Description:** Heatset processes are always equipped with a system that extracts air from the driers and is usually routed to a waste gas treatment system. (see also Section 17.10.2.7)

#### **Achieved environmental benefits:**

Reduction of VOC emissions from driers. Reduction in odour.

#### **Cross-media effects:**

Extraction requires energy.

#### **Operational data:**

See Section 20.11.2.5.



**Applicability:** Generally applied.

**Economics:** See Section 20.11.2.5.

**Driving forces for implementation:** Meeting IED levels. Reduction in odour.

**Example plants:** Generally applied.

**Reference literature:** [8, Nordic Council of Ministers, 1998] [14, Amina, et al., 2002] [4, Intergraf and EGF, 1999, 38, TWG, 2004] [78, TWG, 2005]

### 11.4.3.3 Web offset dryer integrated with waste gas treatment

[192, INTERGRAF, 2017]

*Work in progress – TWG please provide additional information*

#### Description

A web offset dryer with an integrated WGT unit, enabling incoming dryer air to be mixed with a part of the waste gases returned from the WG thermal oxidation system.

#### Technical description

This technique consists of a hot air dryer for the printed web of heatset presses, where the incoming drying air is heated by mixing it with a part of the exhaust gases from the burner or burners that oxidise the VOC content of the outgoing drying air.

The outgoing drying air is fully fed to these burners. The part of the burner exhaust that is not recirculated and used for heating the incoming drying air is emitted.

The cool ingoing dryer air is used to cool the web where it exits the dryer and stop the evaporation of VOCs from the ink on the web. Cooling may also be achieved with the help of metal rollers that are internally cooled with water.

The maximum web temperature is adjustable and will generally be between 140 °C and 190 °C.

There is a limit to the recirculation of the air from the oxidiser to the dryer part since the maximum temperature of the paper web is limited

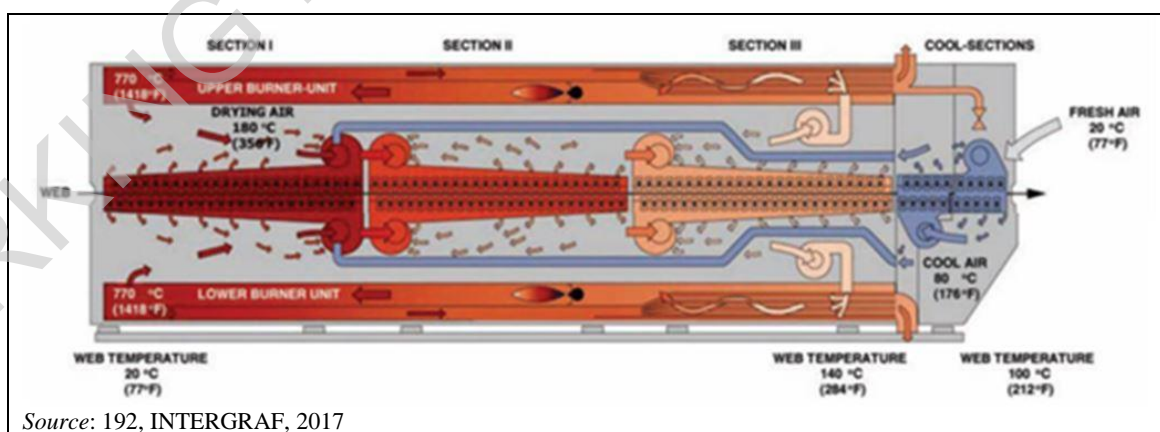


Figure 11.7: Integrated waste gas treatment at the dryer of the heatset web offset

#### Achieved environmental benefits

The main benefit is the avoidance of VOC emissions from the drying of the mineral oils in the heatset inks.

In addition: malodorous smells are avoided. Untreated exhaust gases from heatset dryers are notoriously malodorous.

Energy consumption is considerably lower than in the case of separate dryers and oxidisers. The energy consumption of a separate dryer is saved and, due to the recirculation, the energy consumption of the oxidiser is reduced. This can be illustrated by the fact that the exhaust airflow from these integrated dryer oxidisers is half the airflow of a separate dryer for the same press.

### **Environmental performance and operational data**

Integrated dryer oxidisers are generally capable of attaining values lower than the IED (Annex VII to Directive 2010/75/EU) emission limit value.

The destruction efficiency depends not only on the emission value, but also on the amount of mineral oil evaporated, which in turn depends on the ink coverage of the web and drying temperature.

Typically the VOC concentration in the drying air is some 2 g VOC/m<sup>3</sup>, the emission value well below 20 mg C/m<sup>3</sup>. As a result, the destruction efficiency will be over 99 %. Values of 99.9 % are also achievable.

The dryer oxidisers are designed and produced by specialised companies experienced in supplying the heatset market. Their dimensions depend on the width and speed of the press and the usual ink coverage of the web.

The reliability of these machines is outstanding. This is of course necessary because, in case of a defect, no further printing production is possible: the oxidiser cannot be bypassed.

### **Cross-media effects**

#### **Technical considerations relevant to applicability**

In existing buildings there may be restrictions on the applicability due to the size of integrated dryer oxidisers.

Replacement of existing dryers and their separate oxidisers without replacement of the press is not warranted the savings on energy consumption.

#### **Economics**

No cost information is available

#### **Example plants**

### **11.4.4 Energy efficiency**

Data and information on applied energy efficiency techniques applied in the sector is presented in Section 11.3.1.2.

Detailed descriptions of the techniques can be found in Section 17.5.

## 11.4.5 Cleaning

### 11.4.5.1 ~~Non-VOC and low volatility cleaning agents [Replacement (substitution) and control of VOCs used in cleaning]~~

#### Description

The input of VOCs for cleaning activities can be reduced by combining the following techniques:

- careful handling of the cleaning agent, e.g. closing containers after use;
- applying higher flashpoint HBS (~~Section~~) or VCA (Section 17.9.5) for all cleaning activities;
- reducing the ozone-forming potential (OFP) of the mix of solvents used, see Section 17.6.2.

#### Achieved environmental benefits

The VOC input for cleaning can be reduced to < 5 % of the ink input or the overall OFP can be reduced.

#### Cross-media effects

Using the above solvents may mean that more solvent will require treatment and/or disposal, as less solvent evaporates.

#### Operational data

No information provided.

#### Applicability

Vegetable cleaning agents are not applicable in heatset printing, because the rinse-water can break the paper web.

Only the sheetfed letterpress process can easily use VCAs, but in offset printing, vegetable cleaning agents are not an efficient solution in cleaning blanket cylinders and rubber blankets. The VCAs that are currently available work as swelling agents to rubber blankets and the blankets become unfit for use. It must be taken into consideration that even though VCA has considerable environmental benefits, VCAs are BAT for only some production methods.

#### Economics

No information provided.

#### Driving force for implementation

IED. Occupational health (exposure to solvent vapours). Occupational safety (avoiding explosions in the dryer when the paper web with a cleaning agent reaches the dryer).

#### Example plants

No information provided.

#### Reference literature

[18, UBA Germany, 2003, 38, TWG, 2004] [78, TWG, 2005]

### ~~Automatic high-pressure cleaners for dampening rollers~~

*Proposed for deletion as it is not applied in the sector*

#### Description

~~Dampening rollers can be cleaned by using automatic high pressure cleaners and water. This technique can substitute the traditional cleaning using low flashpoint solvents.~~

#### ~~Achieved environmental benefits~~

~~No VOC emissions and no solvents consumed.~~

**Cross-media effects**

Increased consumption of energy and water. Waste water arises which has to be discharged or treated. Noise levels might increase

**Operational data:** The best result is achieved when the ink is scraped off, as much as possible, before cleaning is started.

**Applicability**

Applicable in offset printing plants using dampening rollers with a molleton covering; however, these are obsolete in heatset in the EU-15. (They occur rarely in sheetfed offset).

**Economics**

No information provided.

**Driving force for implementation**

No information provided.

**Example plants**

No information provided.

**Reference literature**

[8, Nordic Council of Ministers, 1998] [78, TWG, 2005]

**11.4.5.2 Use of non-VOC or low volatility solvents for automatic blanket cleaning**

[192, INTERGRAF, 2017]

**Description**

The use of organic compounds which are non-VOC or VOC of a low volatility as cleaning agents for automatic blanket cleaning

**Technical description**

Automatic blanket cleaning in heatset concerns the cleaning of the rubber blanket cylinder during printing jobs. Paper fibres and ink stick to the rubber blanket and reduce the quality of the printed product. During the production the press is occasionally slowed down or stopped, according to cleaning cycle for the rubber blankets, which are generally eight per heatset press (four colours on each side of the paper web). The cleaning agent consists of a solvent which is often mixed with water. Where water is used, it makes the paper fibres swell and the solvents detach both the fibres and the ink from the rubber blanket.

The length and frequency of the cleaning cycles vary widely, depending on the press, the paper and the print job. The wrong length of the cleaning cycle may result in a web break. Cleaning cycles are reported to take generally between 15 and 40 seconds, but may sometimes take up to three minutes. One cleaning cycle may use between 10 and 700 ml of cleaning agent.

Three types of automatic cleaning exist:

- Brush system: A brush wetted with the solvent-water mixture is briefly held against the blanket. The brush is wiped clean: some 10% of the cleaning agent is collected together with the dirt removed and some 90% is transferred to the paper web.
- Tissue system: Tissue is pressed against the rubber blanket a few times. Both tissue and blanket cylinder are sprayed with cleaning agent. Some 20% of the cleaning agent and the loosened dirt is absorbed by the tissue. The remainder of the cleaning agent is transferred to the paper web. In other cases the tissue is pre-wetted with a cleaning agent.
- Spray system: The blanket cylinder is sprayed with cleaning agent. Cleaning agent and loosened dirt are transferred to the paper web.

In all three systems the paper web transports all or almost all the cleaning agent to the dryer where it evaporates. The VOCs absorbed by the paper web are subsequently abated in the oxidiser. The remainder is collected and disposed of as waste. Therefore the fugitive emissions are negligible.

Since most of the cleaning agents end up in the dryer, the whole system of cleaning method, cleaning agent, dryer and oxidiser must be designed and operated in such a way, that no explosion risk can occur due to the temporary increase of the solvent concentration in dryer and oxidiser during the cleaning cycle. The dryer manufacturer generally specifies limits to which the cleaning agents must fall in. These limits may be expressed in different ways, (flammability, vapour pressure, LEL etc.) but they always result in a very low vapour pressure for the solvents used.

#### **Achieved environmental benefits**

Avoidance of fugitive emissions from automatic blanket cleaning due to negligible evaporation of solvents from cleaning agents used for automatic cleaning. In addition these automatic cleaning systems reduce the amount of manual cleaning and subsequently the use of more volatile solvents.

#### **Environmental performance and operational data**

The combination of low volatility solvents that are used, the short duration of the cleaning cycle and the construction of the cleaning systems make that almost all VOCs are either collected or absorbed in the paper web. As a result no fugitive emissions worth-mentioning result from automatic cleaning where only low volatility solvents are used in the cleaning agent.

#### **Cross-media effects**

The amount of paper waste is influenced by the effectiveness of cleaning agent used. Especially non-VOC cleaning agents may be less effective than low volatility cleaning agents. Where this is the case the use of these non-VOC cleaning agents must be avoided to prevent an increase in paper losses.

#### **Technical considerations relevant to applicability**

All automatic cleaning systems used in large heatset plants are suitable for the application of low volatility solvents in cleaning agents.

#### **Economics**

No additional cost. All large modern heatset presses are equipped with automatic blanket cleaning systems.

#### **Driving force for Implementation**

The main driving forces for implementation are economic advantages (faster cleaning, higher productivity, less manual cleaning), improved working conditions (less manual cleaning, lower exposure to solvent vapours) and increased safety (fewer flammable liquids in use).

#### **Example plants**

All plants that have provided data.

#### **Reference literature**

- VDI-richtlinie VDI 2587: Emission control web offset presses (November 2002)

#### **Automatic cleaning systems for printing and blanket cylinders**

*This technique has been replaced by: "Use of non-VOC or low volatility solvents for automatic blanket cleaning" (see Section 11.4.5.2)*

#### **Description**

The printing and blanket cylinder in large modern heatset offset presses are normally cleaned automatically.

In most machines, the cleaning agent is collected. Some machines use a sheet of tissue that is fed through the cylinders in the same manner as the web. The cleaning agent is sprayed onto the tissue or the tissue is dipped into the cleaning agent, or rolls of tissue are used that already are impregnated with the cleaning agent. Machines applying tissues for cleaning use less cleaning agent, however, the tissues need to be stored and disposed of carefully to prevent uncontrolled emissions (not necessary where non-volatile cleaning agents are used). Other machines spray the cleaning agent onto the paper web to clean the cylinders.

### **Achieved environmental benefits**

Automatic cleaning uses some 10 % less cleaning agents compared to manual cleaning. Fewer wipes are used and, thus, less waste arises.

Automatic cleaning has health and safety advantages. Exposure to vapours and skin contact with cleaning agents is reduced.

### **Cross-media effects**

Automation requires energy. Less waste arises because fewer wipes are used. Liquid wastes may be greater, unless tissue on rolls is used. Liquid waste can be filtered, the solvent can sometimes be reused.

### **Operational data**

Sometimes the contaminated cleaning agents are absorbed in the paper and so, together with the paper discarded, will result in uncontrolled solvent emissions in downstream processes. In some plants, this contaminated paper is put into a dryer to make sure that the solvent emissions are led through the waste gas treatment system. This is not applicable where HBS or low ozone-forming potential solvents are used.

### **Applicability**

Applicable in new and existing plants. Currently, automatic cleaning is standard.

### **Economics**

For one press, the investment is between EUR 60 000-80 000. The investment costs for retrofitting existing presses is much higher than for new presses (1999).

Operating costs are reduced through a shorter cleaning time, a lower consumption of cleaning agent and a reduction of the amount of hazardous waste. In large machines, the cost reduction may outweigh the investment. For small presses, however, it is thought that the environmental advantages do not warrant the investment.

### **Driving force for implementation**

IED and reduced workforce exposure to cleaning agents.

### **Example plants**

No information provided.

### **Reference literature**

[4, Intergraf and EGF, 1999] [18, UBA Germany, 2003] [8, Nordic Council of Ministers, 1998, 38, TWG, 2004] [78, TWG, 2005]

## 12 FLEXOGRAPHY AND NON-PUBLICATION GRAVURE

In flexible packaging plants, a combination of two or more of the following processes are used:

- packaging gravure;
- flexography;
- lamination;
- varnishing;
- digital printing.

Solvents may be used in all of these processes.

### 12.1 General information on the flexographic industry

[194, Technavio, 2017] [196, ERA, 2015] [197, FPE, 2017]

The flexible packaging market in Europe is continuously growing and envisaged to have steady growth in the coming years. One of the key factors for this trend is the increasing demand for plastic-based flexible packaging products.

The main product types of the flexographic industry are:

- confectionary products;
- pharmaceutical;
- personal care;
- pet food;
- meat products;
- dairy products;
- frozen food products;
- fruits and vegetables.

During 2015, the confectionary products segment dominated the market and accounted for more than 22 % of the market share in terms of revenue.

The basic raw materials used are:

- plastic;
- paper;
- aluminium foil.

The European packaging gravure industry is estimated to have a total of 320 printing plants, operating 820 gravure presses. They produce, for example, the following:

- flexible packaging material (film based foil packaging as mono layer or composite to pack foodstuff, confectionery, pharmaceuticals, etc.). Flexible packaging material is used by the large multinational brand owners, as well as by large supermarket chains to pack their brand products filling the shelves of the supermarkets to satisfy the needs of the consumers.
- labels for bottles of the large soft drink manufacturers.
- lids for dairy products (e.g. yoghurt).
- beverage cartons for milk and juice.

The turnover of packaging gravure in Europe amounts to around EUR 15 billion per year. (This number is a rough calculation. The turnover of the individual printer varies according to the product and the substrate which they print.)

There are also about 85 decorative gravure printing plants in Europe, operating 300 gravure presses. They produce primarily:

- base paper for laminate flooring, furniture, kitchen units, etc.;
- gift wrap;
- wallpaper.

The turnover of decorative gravure in Europe amounts to around EUR 2.5 billion per year

Many packaging gravure printers do not have engraving facilities of their own and sub-contract the cylinder manufacturing and engraving. This has become an important industry with an annual production of more than 600 000 gravure printing cylinders. Additionally, there are a significant number of cylinders engraved for the embossing of packaging, wallpaper, hygiene paper, decorative products, etc. The turnover is estimated to be around EUR 0.5 billion per year.

The emissions to water from the electroplating of cylinders are therefore outsourced to specialist suppliers..



## 12.2 Applied processes and techniques in flexography and non-publication gravure

[197, FPE, 2017]

### 12.2.1 Flexography

Flexographic printing employs direct rotary printing using resilient relief plates such as rubber or, as is more likely these days, photopolymers and fast-drying solvent or water-based inks.

Flexography is almost exclusively a reel or webfed process. It is a simple method of printing normally with a very easy inking system using one main dispensing roller with a rough surface.

Specially designed flexo presses now produce a wide range of printed products. It is particularly suitable for long-run web printing, and is very adaptable to a wide range of substrates – from thin paper to heavy corrugated cardboard, thin cellophane to thick flexible sheeting, vinyls and foils. The main applications of the process are flexible packaging, cartons for liquids, some newspapers, paperback books, labels, paper/plastic bags, cartons/packaging and wall coverings.

Plants producing and printing corrugated cardboard use sheetfed presses. The corrugated cardboard is cut into rigid sheets which go through the whole press horizontally. The presses are either 'bottom printers' or 'top printers', i.e. print on the underside or topside of the substrate.

#### Inking unit

Many different products and substrates may be printed on the same press and, therefore, inks may have to be changed regularly. Food packaging inks have changed over the years from those based on aromatic solvents to aliphatics, that is, from toluene and xylene to ethanol, MEK, acetone and ethyl acetate. These inks dry by evaporation; however, UV curing inks are also used [38, TWG, 2004].

The ink has low viscosity, is fluid and traditionally held in an inkpan from where it is picked up by a rotating rubber fountain roll. The fountain roll subsequently delivers the ink to the metering roll. Excess ink is removed from the metering roll with a doctor blade before it is transferred to the printing plate.

A more modern system is the chamber doctor blade where the ink reservoir is connected with a fountain head from which the ink is supplied directly onto the ink-metering (anilox) roll. As the ink is circulated by pumps in the box-like construction, the transfer of ink onto the anilox roll is independent of the press speed. Two doctor blades, connected to the fountain head, fit closely against the anilox roll.

#### Ink-metering (anilox) roll

In a flexo press, the ink is transferred from the ink-fountain to an ink-metering (anilox) roll. The ink-metering roll is ceramic and covered with cells by which the ink is metered out onto the printing plate; how much depends on the depth and structure of the cells, the pattern formation and the screen count. The cells can be mechanically or laser engraved, and if necessary can be re-engraved.

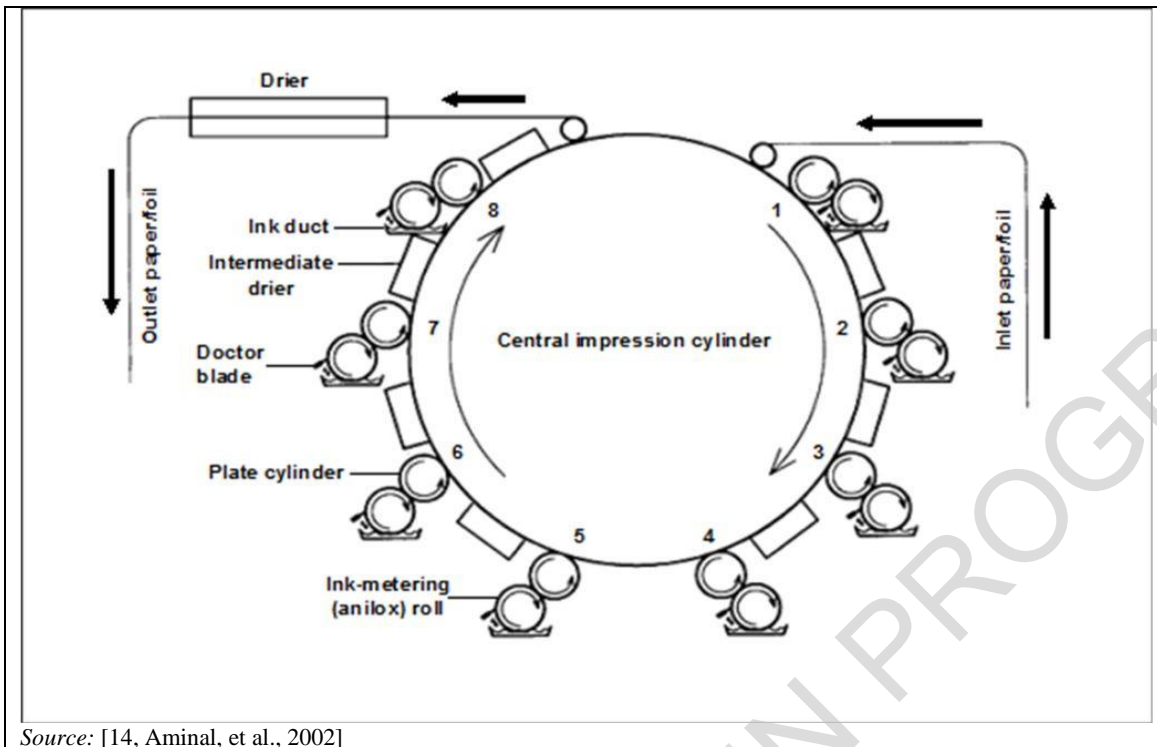
#### Plate cylinder

The plate cylinder is usually a steel cylinder onto which the printing plates are mounted with a double-sided adhesive. Flexo printing plates are usually made of UV sensitive polymers or rubber, and are resilient and flexible, which has given the technique its name.

#### Impression cylinder

Flexographic printing machines may be designed as a series of units, or in compact form. In series construction, each printing unit has its own impression cylinder and are lined up in stands one behind the other. In compact form, several printing units (up to a maximum of eight) may

be supported on both sides or, in the case of small presses, hung from one side (cantilever type) of a central impression cylinder. This is also known as a satellite press [38, TWG, 2004].



**Figure 12.1: Eight-colour flexo press with a central impression cylinder (satellite press)**

### Cleaning

Cleaning of printing plates and machine parts is done with solvents similar to those in the inks or vanishes. Ultrasound cleaning and cleaning with high pressure powder can be used for persistent contamination.

### 12.2.2 Gravure

[1, INTERGRAF and EGF, 1999] [8, Nordic Council of Ministers, 1998] [3, IMPEL, 2000] [78, TWG, 2005] [197, FPE, 2017]

In gravure printing, the image consists of small indentations in a smooth surface of a cylinder. This consists of a steel base which is plated with copper and covered with a thin layer of hard chromium. It tends to be a more specialised process than either relief or litho printing, being mainly used for long runs as the cylinder making costs are relatively high. In this process, the cylinder is flooded with ink, and the surface scraped clean to leave ink only in the recessed, image areas.

Gravure is used for printing two major graphic products: publications which is discussed in chapter 13 of this document and flexible packaging (e.g. packaging for tobacco industry). Minor graphic applications are labels, gift wrapping paper, cardboard packaging, banknotes and postage stamps. Outside the graphic industry, this method is used for the printing of wallpaper, imitation wood (laminates) and imitation tiles for floors and walls.

**Table 12.1: Main technical characteristics of packaging gravure presses**

	<b>Packaging gravure</b>
Web width	Up to 2 000 mm
Printing units	Generally between 6 and 10, often 8 colour units + one lacquering unit and/or laminating unit
Production speed	Generally some 250 – 400 m/min; also dependent on diameter of cylinders in use
Construction	Units in line, each printing a separate colour <del>on the same side of the substrate</del>
Colours	All colours, often also white basis
Substrates	Paper, many different kinds of plastic films, metallised paper and plastic, aluminium foil; often multi-material, multilayer substrate
Solvents in use	Ethyl acetate, ethanol, MEK and others. Mostly in mixtures in Northern Europe <del>and pure in Italy</del>
Abatement techniques	<del>Incineration</del> RTO mostly and solvent recovery <del>mainly in Italy and sporadically elsewhere</del>

Most packaging gravure presses have a web width ~~of about~~ wider than one metre, ~~or sometimes a bit wider~~. They print eight or even ~~ten~~ more colours ~~on one side~~, with each press unit printing one colour [15, CITEPA, 2003].

Today, gravure is almost totally a webfed process, although sheetfed presses are available running at up to 10 000 sheets per hour. These have hot air dryers and are aimed at the specialised markets of high quality decorative effects using metallic inks on metallised papers and foils. They are, however, seldom used at present, presumably because of the high costs of cylinder making, which make high (web) run lengths more economic [1, INTERGRAF and EGF, 1999].

### **Inking unit**

[8, Nordic Council of Ministers, 1998] [15, CITEPA, 2003]

The high speed of gravure presses requires the use of fast drying inks, which are dried between colours in dryers. Therefore, in gravure, inks are low in viscosity and nearly all of them are solvent-based. In packaging printing inks, ethanol and ethyl acetate are used almost exclusively. The solvents are evaporated by heat and air in drying sections, see Figure 12.1 which shows that each printing unit is equipped with a dryer on top [38, TWG, 2004].

Solvent vapours from the inks in the packaging gravure are normally treated with RTO or recovered. ~~incinerated, although in Italy they are often recovered.~~

Water-based gravure inks have not yet proved very successful and, until now, only used sporadically in packaging printing. ~~The use of water-based gravure inks in the United States has now ceased~~ [8, Nordic Council of Ministers, 1998] [38, TWG, 2004].

### **12.2.3 Laminating and varnishing in flexible packaging**

Flexible packing materials are often multilayer materials built up by lamination and with a protective coating called varnishing. The processes are technically similar to packaging gravure printing. While no image is printed, the substrate is usually totally covered (i.e. 100 % covered). Solvent based or less solvent adhesives (1 oder 2 component), water based adhesives ~~Solvent-based, water-based and chemically reactive (2 component) adhesives~~ and resins are used.

## 12.3 Current consumption and emission levels

[197, FPE, 2017], [155, TWG, 2016]

In flexible packaging plants, a combination of two or more of the following processes are used:

- packaging gravure
- flexography
- lamination
- varnishing.

Solvents may be used in all of these processes.

### Mass balances – flexible packaging

[18, UBA Germany, 2003]

In 1999, the results of an inventory amongst packaging printing plants in Germany were reported. One of the results of this inventory was that the performance data from different units of different plants were compared and used to simulate a virtual plant that could meet the legal requirements, especially those of the Solvent Emissions Directive. In the following section, a mass balance for a good practice plant selected from the inventory is reported, followed by data for the virtual plant.

#### A good practice plant

In this section, data of a good practice plant from this inventory are reported along with the mass balances of the virtual plant. This virtual plant as explained above is not an existing plant, but made up of well performing units from different existing plants. Notice that the data from the existing good practice plant do not differ that much from the virtual plant. The operational data of the good practice plant are as follows:

- the plant is operational for six days a week in three shifts. It has three units each with three flexography central impression cylinder presses with a web width of 1.30 metres
- the end product is printed forms that are wound up after printing and delivered as an intermediate product to brand name article manufacturers; finishing operations are not done at this plant
- in two units, mainly solvent based products are applied (i.e. inks and cleaning agents) and in one unit, 85 % of the products used are water based
- solvents for viscosity control of the inks are piped directly to the inking unit
- for air emissions control, a catalytic waste gas treatment system with heat recovery is installed. The extraction systems of the printing presses are equipped with circulating air techniques which are controlled by measuring the solvent concentration
- the cleaning of the inking unit is done in an enclosed cleaning machine equipped with an integrated solvent recovery
- effluent from cleaning activities is treated by applying ultrafiltration (for water based inks).

The mass balance of the good practice plant is shown in **Error! Reference source not found.**

INPUT	Amount	Unit	Notes	OUTPUT	Amount	Unit	Notes
				Products			
				Intermediate printed products	9700	t/yr	Paper and ink
				Waste			
Material				Paper/misprints	740	t/yr	
Printing substrate	10433	t/yr		Ink residues	41	t/yr	With approx. 10.8 t VOC
Printing inks;	576	t/yr	Of which approx. 1/4 water-based				
VOC content	189	t/yr					
Thinners	316	t/yr					

(solvents for viscosity adjustment)							
Water for cleaning and thinning	666	m <sup>3</sup> /yr		Mixture of cleaning agents and water	15	t/yr	With approx. 9.8 t VOC
				Process effluent	545	m <sup>3</sup> /yr	
Water for cooling and air conditioning	51866	m <sup>3</sup> /yr					
Wipes	144100	items/yr		Wipes	144100	items/yr	With approx. 2.5 t VOC
VOC total	505	t/yr		VOC in waste	23	t/yr	
Energy				Exhaust gas			
Energy in total	3670	MWh/yr		Volume flow	72.45 × 10 <sup>6</sup>	m <sup>3</sup> /yr	
Gas energy	350	MWh/yr		VOC in purified gas	1.38	t/yr	384 t/yr VOC destroyed
Electric energy	3320	MWh/yr		NO <sub>x</sub> in purified gas	4.70	t/yr	
				CO in purified gas	2.72	t/yr	
				Fugitive			
				VOC fugitive	96	t/yr	approx. 19 % of the input

Note: [38, TWG, 2004]:

- three shifts and six day working are unusual in flexographic printing: the presses are not expensive enough. This is usually associated with a packaging gravure plant
- web width 130 cm is rather wider than normal
- catalytic incineration: nowadays always regenerative
- effluent treated by ultrafiltration is unusual: normally effluent is insignificant.

Table Mass balance of a good practice flexo printing plant [18, UBA Germany, 2003, 38, TWG, 2004]

The following points should be noted from the information exchange [38, TWG, 2004] [78, TWG, 2005]

- these data may indicate good practice for one plant for certain jobs and conditions but may not be typical of the industry
- ink residues = 41 t/yr with 10.8 t solvent = 26 %: this is not ink (press ready ink has 80 % solvent) but sludge from the distillation of cleaning agents
- 385.38 t/yr in the untreated waste gas is an average of 5.3 g/Nm<sup>3</sup>. This is too high for usual flexo work and is only reached if a high level of varnishing and lamination (which is not shown in **Error! Reference source not found.**) is done with a high air recirculation rate. This also implies that a significant amount of printing is using white ink and therefore not printing on paper
- VOC in purified air is an average of 19 mg/Nm<sup>3</sup>, which expressed in mg C is some 50 % lower (about 10 mg/Nm<sup>3</sup>) with an incinerator efficiency of >99.5 %. Industry believe this efficiency is too low to be realistic. However, it is reported as normal good practice in Germany, with raw gas concentrations in the range 1–8 g/Nm<sup>3</sup> and an outlet concentration below 20 g/Nm<sup>3</sup>.

It should be noted that when comparing the consumption and emission data of this good practice plant with those from the virtual plant, all auxiliary processes with their additional

consumptions and emissions are also recorded. The estimated data of the virtual plant are estimations of the consumption and emissions of each specific unit on its own.

### A virtual plant

In order to draw an objective picture of the range of consumption and emission values that are achieved in practice, two different driving styles of the virtual plants are described. On one hand, production with solvent based inks, and on the other hand mixed production with water-based inks and a solvent based cover varnish. The virtual plants have the following characteristics as shown in **Error! Reference source not found.:**

<b>Printing machines</b>	Flexography central impression cylinder plant; eight inking units, size 127 x 100 cm, web velocity up to approx. 250 m/min
<b>Driers</b>	Indirect heating of interim drier and bridge drier by heat transfer oil, circulating air technique controlled by monitoring the solvent concentration
<b>Finishing processes</b>	Reel slitter, cross cutter, rewinder
<b>Conditions of production</b>	280 production days/yr, in three shifts; 6525 operating hours/yr with 70 %* production printing time; in total 4560 printing production hours/yr
<b>Products</b>	Paper wrappers 70 g/m <sup>2</sup> <u>Solvent based:</u> six colours, surface coverage 155 %, in application 4.98 g/m, web velocity 150 m/min <u>Mixed process:</u> six colours + cover varnish, surface coverage 255 %, ink application 4.9 g/m <sup>2</sup> + cover varnish 2.5 g/m <sup>2</sup> , web velocity 150 m/min
* Note: 70 % printing production time is higher than can be achieved in practice [38, TWG, 2004]	

Table: Machinery and conditions of production of the virtual flexo printing plants [18, UBA Germany, 2003]

The specific consumption and emission values are significantly dependent upon the manufactured products and will increase with:

- decreasing print volume;
- increasing number of colour change sequences;
- extremely high demands on the printing quality, or difficult printing images;
- decreasing paper quality;
- increase of surface to cover.

From the virtual plants, mass balances are calculated. Average VOC consumptions and emissions in relation to one tonne ink that is used are shown in **Error! Reference source not found.** and **Error! Reference source not found.** as are the average input of material and output of waste of the virtual plants. For a production by gravure, the admixture of thinners (VOC input) and the corresponding VOC emissions stemming from the ink would be 10–20 % higher. These values are average values, which can, depending on the above mentioned parameters, vary in practice by +/- 20 %.

1000 kg printing ink containing 500 kg VOC	Process step	Output
+ 731 kg thinner (100 % VOC)	Solvent for viscosity adjustment [38, TWG, 2004]	
21875 kg paper	Printing process	160 kg fugitive VOC losses 1900 kg misprints/paper waste 90 kg ink residues
70 kg cleaning agent (100 % VOC) 120 wipes	Interim cleaning	45 kg fugitive VOC losses 120 wipes with approx. 1.4 kg ink residues + 3 kg solvents
	Ink drying	1063 kg VOC in the extracted untreated air

		<sup>2</sup> 6.80 g/m <sup>3</sup> VOC in 133100 Nm <sup>3</sup> after treatment
	Finishing	Waste paper
Total VOC input: 1301 kg		Total VOC output:  205 kg fugitive (16 % of input) 1060 kg treated approx. 2–3 kg in treated gas approx. 33 kg in waste
Note: <sup>1</sup> The figure for thinner is too low: press-ready ink is 72 % solvent [38, TWG, 2004] <sup>2</sup> 6.80 g/m <sup>3</sup> VOC is too high for flexo-printing, and probably includes laminating and/or varnishing		

Table: VOC and waste balance of solvent-based virtual flexo printing plant [18, UBA Germany, 2003]

1000 kg printing ink * containing 31 kg VOC	Process step	Output
516 litres water 625 kg print varnish (containing 156 kg VOC) 198 kg thinner (100 % VOC)	Ink conditioning	
21875 kg paper	Printing process	58 kg fugitive VOC losses 1900 kg misprints/paper waste 140 kg ink residues
1200 l water 120 wipes	Interim cleaning	1200 l effluent containing approx. 18 kg COD 120 wipes with approx. 1.4 kg ink residues
	Ink drying	323 kg VOC in the extracted untreated air 1.38 g/m <sup>3</sup> VOC in 234370 m <sup>3</sup> air of 69 °C after treatment
	Finishing	Waste paper
Total VOC input: 385 kg		Total VOC output:  58 kg fugitive (15 % of input) 320 kg treated approx. 3 kg in treated gas approx. 4 kg in waste
* Note: ink appears to be water based, but this is not clear [38, TWG, 2004]		

Table: VOC and waste balance of mixed-process virtual flexo plant [18, UBA Germany, 2003]

### Consumptions—flexible packaging

### 12.3.1 Consumption

#### 12.3.1.1 Organic solvents

[1, INTERGRAF and EGF, 1999] [155, TWG, 2016]

Reported values of total organic solvent consumption show a range from 40 up to 390 g of solvent per kg of printed surface. The relevant range of reported values for total solvent consumption expressed against the printed surface of printed surface is from 1 up to 30 kg of solvent per 1000 m<sup>2</sup>. It was not possible to differentiate on the basis of substrate material as most of the reported plants use a range of substrate types, e.g. polypropylene, polyethylene, polyester, polyamide, aluminum or paper foil, cardboard (155, TWG, 2016).

Table 12.2 shows a choice of typical organic solvents that are employed in package printing processes together with their field of application. Table 12.3 shows an overview of typical organic solvents that can be found in package printing processes applying water-based inks, adhesives or varnishes.

**Table 12.2: Typical solvents used in solvent-based packaging printing processes**

Solvent	Vapour pressure (kPa)	Field of application
Ethyl acetate	9.2	Thinner, cleaning agent
Ethanol	5.9	Solvent in ink, cleaning agent
Mixtures of ethanol and ethyl acetate		Mix depends on required drying time
Isopropanol	4.3	Solvent in ink, cleaning agent
Isopropyl acetate	6.1	Viscosity adjuster
Methyl ethyl ketone	10.5	Siccative; often used as solvent in adhesives and some varnishes
n-Butanol	1.2	Retarder
Methoxy propanol	1.1	Retarder
n-Propanol	2.5	Retarder
Ethoxy propanol	0.65	Retarder
Various esters		Plasticiser
<i>Source:</i> [18, UBA Germany, 2003, 38, TWG, 2004]		

**Table 12.3: Typical solvents used in water-based packaging printing processes**

Solvent	Vapour pressure (kPa)	Field of application
Ethanol	5.9	Solvent in ink, siccative, cleaning agent
Isopropanol	4.3	Solvent in ink, cleaning agent
n-Propanol	2.5	Solvent in ink
Special naphtha	4.0–8.5	Cleaning agent (rarely used as most packing is for food)
White spirit	0.15–1.0	Cleaning agent (rarely used as most packing is for food)
<i>Source:</i> [18, UBA Germany, 2003]		

Apart from organic solvents in purchased printing inks, other relevant solvent quantities are used in ink thinning (viscosity control) and for several cleaning jobs. Especially in the area of viscosity control, the gravure and flexography processes are different.

Table 12.4 presents typical mean values of specific VOC uses.



It is important to note that the solid:solvent ratio in inks 'as bought' will vary enormously from plant to plant. Ink is delivered to certain specifications. In one extreme; it is delivered 'almost press-ready', with a solvent content of close to 75 % (a small final dilution is done at the press). At the other extreme, ink is delivered as a 'paste' with a solvent content of about 30 %. The pastes are mixed and diluted in the ink department to 'almost press-ready'. Again, the final dilution is made at the machine. In addition, a few years ago the 'normal' percentage of solvent in ink 'as bought' was between 50 % and 60 %, this is now no longer the case. In larger plants, inks are today bought as 'paste' and diluted in-house [78, TWG, 2005]:

**Table 12.4: Specific VOC use in package printing processes**

Printing process	VOC used expressed as % of purchased ink (wt-%) in the following areas:						Total VOC used as % of purchased ink (wt-%)	
	Printing inks <sup>(1)</sup>		Thinners for inks		Cleaning agents			
	Average	Range	Average	Range	Average	Range	Average	Range
Gravure solvent-based	6.0	4.0–7.0	10.1	7.0–12.0	1.7		17.8	12.7–20.7
Flexography solvent-based	6.0	4.5–7.5	8.1	5.0–9.5	1.4		15.5	10.9–18.4
Gravure water-based	5	0–20	2	0–5	10	0–15	17 <sup>(2)</sup>	0–40
Flexography water-based	5	0–20	2	0–5	10	0–15	17 <sup>(2)</sup>	0–40

NB: [38, TWG, 2004, 78, TWG, 2005]  
<sup>(1)</sup> The machine-ready ink will always contain about 80 % solvent. An ink bought with a higher solvents content will require less solvent for thinning (viscosity adjustment). Averages for solvent-based inks: gravure tends to be slightly over 80 % and flexo tend to be slightly under 80 %.  
<sup>(2)</sup> Average for water-based inks of 17 % is too high.  
Source: [18, UBA Germany, 2003]

Table 12.4 shows, for example, that in a gravure solvent-based printing process, an average of 1.78 kg VOC per kg purchased ink input is used in the production and auxiliary processes of the plant. The range in this example is 1.27–2.07 kg VOC per kg purchased ink input.

On-site solvent recovery is only applicable to cleaning agents and will reduce the amount of cleaning agents that have to be purchased. This means that for the specific VOC uses per kg ink input, as mentioned in ~~Error! Reference source not found.~~, the data concerning the column 'cleaning agents' are reduced by about 50 %.

#### 12.3.1.1.1 Printing inks and varnishes

[18, UBA Germany, 2003] [4, Intergraf and EGF, 1999] [8, Nordic Council of Ministers, 1998] [9, VITO, 1998, 78, TWG, 2005]

##### Types of inks used – solvent-based

The most common solvents used in solvent-based package printing are ethanol and ethyl acetate. Furthermore, flexo printing plants use isopropanol, n-propanol, methoxy propanol and ethoxy propanol, and gravure printing plants also use methyl ethyl ketone, i-propyl-acetate and n-propyl-acetate. The choice of solvent used in the ink depends on the printing substrate.

During printing, the viscosity of the ink is adjusted as required, or is kept at its preset level by adding compatible solvents. Newly mixed inks are always produced slightly too viscous to allow exact adjustment to be made at the press.

Flexo ink is either solvent-based or water-based. Gravure ink is almost always solvent-based and water-based inks are rarely used. Table 12.5 shows an average composition of a basic recipe for solvent-based inks. The ink solvent concentration varies. ~~see Section Error! Reference source not found., above.~~ Machine-ready inks might contain up to about 80 %

solvent and 20 % solids. Varnishes also contain about 80 % solvents [38, TWG, 2004][78, TWG, 2005]

**Table 12.5: Average basic recipe for solvent-based flexo printing inks**

Component	Contents	Concentration (wt-%)
Binding agent:		
- solvent component	Normal drying solvents: e.g. ethanol, n-propanol, isopropanol	60–80
	Fast drying solvents: e.g. ethyl acetate, i- and n-propyl acetate, MEK, naphthas	
	Slow drying solvents: e.g. methoxy propanol, ethoxy propanol	
- binding agent component	Cellulose derivatives (e.g. nitro-cellulose), polyvinyl butyrates, PVC, polyamides	10–2
Colourants	Inorganic and/or organic pigments	10–5
Colour auxiliary agents	e.g. softeners, waxes, slide agents, EDTA (no longer used in Germany)	1–6
NB: Physical properties: solids content: 25–40 %; net calorific value: > 20 MJ/kg; flashpoint < 21 °C. Source: [18, UBA Germany, 2003] [54, BMLFUW Austria, 2003]		

A typical formula for a flexo ink to be printed on paper is shown in Table 12.6 and a typical formula for a hydrocarbon solvent-free ink for paper is shown in Table 12.7.

**Table 12.6: Typical flexo ink for paper as bought**

Component	Concentration (wt-%)
<b>Pigment</b>	20
<b>Maleic resin varnish</b>	16
<b>Nitrocellulose varnish</b>	38
<b>Wax</b>	4
<b>Plasticiser</b>	4
<b>Ethanol</b>	11
<b>Isopropyl acetate</b>	7
Source: [4, Intergraf and EGF, 1999]	

**Table 12.7: Typical hydrocarbon solvent-free flexo ink for paper as bought**

Component	Concentration (wt-%)
<b>Organic pigment</b>	12
<b>Alcohol-soluble polyamide resin</b>	22
<b>Nitrocellulose (dry weight)</b>	4
<b>Wax</b>	4
<b>Fatty acid amine</b>	1
<b>Ethanol</b>	29
<b>n-propyl alcohol</b>	18
<b>n-propyl acetate</b>	10
Source: [4, Intergraf and EGF, 1999]	

Flexo inks for plastic substrates and metallic foils vary considerably from inks that are used on paper. The solvents used have changed over time, partly as a result of food packaging requirements and regulations. Aromatic ink solvents have been replaced by ethanol and ethylacetate and some MEK in adhesives and varnishes [4, Intergraf and EGF, 1999] [93, COM, 2002/4]

Apart from the general basic recipe shown in Table 12.5, other examples of typical inks used in the gravure printing process can also be found; one of these is shown in Table 12.8. Of course, the ink formulation will vary considerably depending on the printing substrate, the press parameters and end use of the finished product.

**Table 12.8: Typical recipe of a gravure ink as bought**

Component	Concentration (wt-%)
Pigment	4–12
Extender pigment	0–8
Resin	10–30
Plasticiser/wax/additives	2–10
Solvents	40–60
<i>Source: [1, INTERGRAF and EGF, 1999] [38, TWG, 2004]</i>	

In general, the solvent choice will depend on many aspects, such as a need to avoid a solvent attack on a film or solvent coating, and to ensure that as little solvent as possible remains in the product, especially with food packaging. Only very rarely is it necessary to deviate from ethanol, ethylacetate and mixtures of the two. Occasionally MEK, acetone, toluene (packaging for medical purposes) or isopropanol (non-food paper product) may be found [4, Intergraf and EGF, 1999, 78, TWG, 2005].

#### **Types of inks used – water-based**

Table 12.9 shows an average composition of a basic recipe for water-based inks applied in gravure printing. In water-based inks, the water concentration in the purchased printing inks is might be normally in the range of 50–60 %. Aqueous dispersions, such as styrene-acrylate copolymer, are mainly used as binding agents. According to the purpose and the desired resistances, acid resins which are transformed into a water-soluble form by saponification with alkaline substances (ammonia or amines), are employed for modification. During the drying process, the amines or ammonia escapes and the binding agent resins once more become insoluble in water [18, UBA Germany, 2003].

As drying additives, ethanol and isopropanol are added in low concentrations of mostly below 5 %. Only in cases of very special demands to the drying velocity, e.g. on thin papers, can this percentage increase up to 25 % [18, UBA Germany, 2003].

In most cases, the recipes contain additives such as anti-foam agents, wetting agents and biocides. Dilution can be made with water [18, UBA Germany, 2003].

**Table 12.9: Average basic recipe for water-based gravure inks**

Component	Contents	Concentration (wt-%)
Binding agent:		
- aqueous solvent component	Water	50–75
- organic solvent component	Alcohols (e.g. ethanol, isopropanol)	0–13
- other binding agent component	e.g. polyester and acrylate resins, polyvinyl acetate	10–20
- other binding agent component	Ammonia, amino acids	1–5
Pigments	Inorganic and/or organic pigments	10–20
Colour auxiliary agents	e.g. waxes, (softeners and complex formers are not used in Germany)	1–5
	Saponification agents	1–5
NB: Physical properties: solids content: 25–40 %; net calorific value: > 10 MJ/kg; approx. pH value: 8. Source: [18, UBA Germany, 2003] [54, BMLFUW Austria, 2003] [38, TWG, 2004]		

A typical recipe of a water-based gravure ink for printing on coated paper, might be as shown in Table 12.10

**Table 12.10: Typical recipe of a water-based gravure ink for coated paper as bought**

Component	Concentration (wt-%)
Acrylic resin	32
Water	30
Pigment	15
Acrylic dispersed phase polymer	15
Alkali	2
Anti-foam	1
Isopropanol	3
Wax dispersant	2
Source: [1, INTERGRAF and EGF, 1999] [18, UBA Germany, 2003, 78, TWG, 2005]	

A typical, well-performing, water-based flexo ink used for printing on paper and cardboard is shown in Table 12.11

**Table 12.11: Typical recipe of a water-based flexo ink for paper and cardboard as bought**

Component	Concentration (wt-%)
Acrylic emulsion	50
Water	20
Pigment	25
Monoethylamine	2
Polyethylene wax	3
Organic anti-foam	< 1
Source: [1, INTERGRAF and EGF, 1999]	

Water-based inks for printing onto polyethylene and polypropylene would typically have much higher acrylic dispersed polymer contents (40 %) and much lower acrylic resin percentages (5–10 %).

Cartons are almost always varnished, increasingly with water-based overprint varnishes. A water-based heatseal resistant varnish, suitable for overwrapping with film, might have the formula shown in Table 12.12.

**Table 12.12: Typical water-based varnish for cartons in gravure printing processes**

Component	Concentration (wt-%)
Hard acrylic resin	15
Isopropanol	20
Water	15
Acrylic emulsion	35
Amine or ammonium hydroxide	2
Wax emulsion	5
Wax dispersion	5
Release agent	2
Anti-foam	1
<i>Source: [1, INTERGRAF and EGF, 1999]</i>	

### Types of inks used – UV

UV printing inks are increasingly applied in flexo printing. These inks consist of binders, additives, photo-initiators and the dyestuff which are all solid materials and contain no solvent. Drying, or more correctly, curing is the consequence of the cross-linking or polymerisation of the printing film resulting from the printed surface being exposed to short-wave UV light.

### Amounts of inks used

The amount of both solvent- and water-based ink consumed depends largely on the colour of the ink and only slightly on the printing substrate or printing method. Table 12.13 shows some average values.

**Table 12.13: Average ink application values**

Colours	Ink application (for theoretical complete coverage) (g/m <sup>2</sup> )
White	1.5–2.0
Spot colours	1.0–1.5
Half tone	0.5–1.0
<i>Source: [38, TWG, 2004].</i>	

The surface that is covered with ink, especially in flexible packaging, is determined by several complex customer requirements, such as:

- the quality of the image that has to be printed and the type of printing substrate;
- the need to prevent light reaching the product inside (usually food);
- the need for an air-tight barrier and prevention of migration of smells;
- for printing materials that are difficult to moisten (e.g. foils), a primer is applied that acts as an adhesive agent and is applied in the first printing run;
- for improvement of the effect of the printed colours on transparent plastic or metal foils, the surface is first printed in matt white before applying the final colours;
- improving the characteristics of the coloured surface, e.g. UV or abrasion resistance, a full-surface varnishing is employed as a last step in the printing job.

For example, on corrugated cardboard, the surface covered with ink is usually < 20 %, while for high quality consumer goods (e.g. chocolate packages) a surface coverage of > 400 % is reached by using a series of coatings. So-called 'flat tints' reach 100 % coverage for white ink on plastic, and also varnishes and adhesives have a large impact on the total surface covered [38, TWG, 2004].

### 12.3.1.2 Cleaning agents

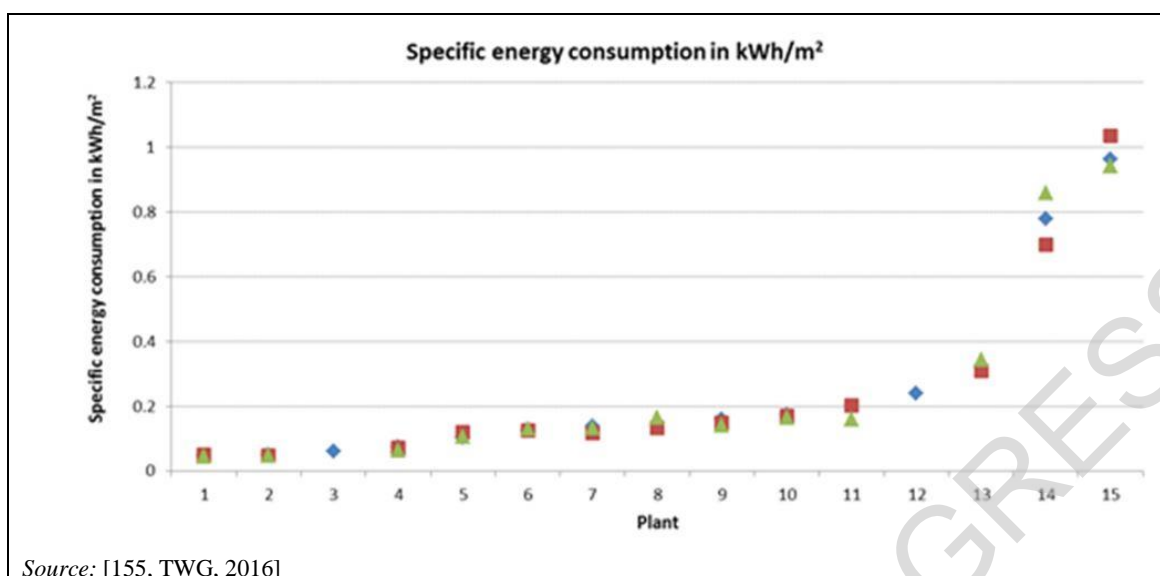
For cleaning the presses, primarily the same solvents as employed in the inks are used. Plants using water-based ink systems are usually cleaned with water, partly with admixtures of alkaline substances, such as sodium bicarbonate, and tensides. Mixtures of water with water-dilutable organic solvents are also used. In order to remove dried inks from the small cavities in gravure cylinders and anilox rollers, ultrasonic equipment or other solvent-free cleaning techniques may be used. High pressure water jets are also used on anilox rollers [18, UBA Germany, 2003] [4, Intergraf and EGF, 1999] [38, TWG, 2004].

### 12.3.1.3 Adhesives in lamination

~~Traditionally, most laminating was done with solvent based systems. Such adhesives gave good levels of gloss and bond strength. Press ready varnishes contained about 80 % solvents. Alternatives to solvent based systems are the epoxy or the urethane systems, in which two constituents react together to form a very tough film. Mixing of the two-components is required but there will be no solvent emissions. Solvent-free adhesives or UV curing laminating adhesives are also applied. Water based adhesives may be used when paper needs to be adhered to aluminium or plastic foil. The water evaporates through the paper. Water based adhesives have the lowest use~~[4, Intergraf and EGF, 1999] [38, TWG, 2004].

### 12.3.1.4 Energy and resources

The reported values for specific energy consumption from flexographic installations are presented in Figure 12.2.



Source: [155, TWG, 2016]

**Figure 12.2: Reported values of specific energy consumption from flexographic installations (kWh/m<sup>2</sup> of finished product)**

The main energy-saving techniques that were reported are:

- air extraction and energy recovery from drying processes;
- heat recovery from waste gas abatement;
- use of waste heat from thermal oxidiser for thermal oil heating;
- exhaust air heat exchanger in ventilation systems;
- central waste gas treatment with variable frequency drives;
- thermal insulation of tanks and vats with heated liquids, oil valves and flanges;
- CCHP (combined cooling, heat and power) – trigeneration;
- reduced air ventilation at idle operation or maintenance;
- optimisation of dryer efficiency in printing and laminating.

### Energy

The specific energy consumption of the good practice flexo plant described in Section **Error! Reference source not found.** is 0.4 MWh/tonne product. Note that this good practice plant is equipped with a waste gas treatment with heat recovery [38, TWG, 2004].

The energy balance of the virtual solvent based flexo plant as described in **Error! Reference source not found.**, in relation to the use of 1 tonne ink, is shown in **Error! Reference source not found.**

Input based on 1000 kg printing ink	Process step	Output
<i>Included in the printing process</i>	Ink conditioning	
3185 kWh electric drives	Printing process	
4010 kWh electric cooling		
580 kWh electric compressed air		
<i>Included in the printing process</i>	Interim cleaning	
2800 kWh thermal oil (approx. 51 % intermediate driers and 49 % final or bridge driers)	Ink drying	
985 kWh electric fans		
<i>Included in the printing process</i>	Finishing	

350 kWh electric fans	Waste gas treatment	5785 kWh thermal from energy recovery
Total input: 8910 kWh 6110 kWh electrical 2800 kWh thermal		2985 kWh thermal net gain  Total output: 5785 kWh thermal

Table: Energy balance of the virtual solvent-based flexo printing plant [18, UBA Germany, 2003] [38, TWG, 2004]

The energy balance of the mixed process flexo printing virtual plant as described in **Error! Reference source not found.**, in relation to the use of 1 tonne ink, is shown in **Error! Reference source not found.** [38, TWG, 2004].

Input based on 1000 kg printing ink	Process step	Output
<i>Included in the printing process</i>	Ink conditioning	
3180 kWh electric drives 1010 kWh electric cooling 580 kWh electric compressed air	Printing process	
<i>Included in the printing process</i>	Interim cleaning	
5500 kWh thermal oil (approx. 42 % intermediate driers and 58 % bridge driers) 980 kWh electric fans	Ink drying	
<i>Included in the printing process</i>	Finishing	
1300 kWh thermal 350 kWh electric fans	Waste gas treatment	0
Total input: 13000 kWh 6200 kWh electrical 6800 kWh thermal		Total output: 0

Table: Energy balance of the mixed-based virtual flexo printing plant [18, UBA Germany, 2003]

UV- and water-based inks need more energy to dry than solvent-based inks. UV inks need UV light to cure it and special equipment on the press. As the high energy supply to the lamps is turned into heat, large installations for cooling are also needed [8, Nordic Council of Ministers, 1998]. For water-based inks, an increase in the energy consumption of the dryers of some 10 % is often found [4, Intergraf and EGF, 1999].

## 12.3.2 Emissions

### 12.3.2.1 VOC emissions

At EU 25 level for 2000 (according to the RAINS model) NMVOC emissions were 127.56 kt representing 1.2 % of total NMVOC emissions. The total activity was 91.69 kt of non-diluted ink and an average emission of 1.4 kg NMVOC/kg non-diluted ink [80, EGTEI, 2005]:

The mass balance shown in **Error! Reference source not found.**, shows that for a flexo printing plant, fugitive VOC emissions of 19 % of the solvent input are achievable although the measurement method is not clear. For the virtual plants described in **Error! Reference source not found.** and **Error! Reference source not found.**, fugitive emissions of 16 % and 15 % respectively, are calculated to be achievable for a 100 % solvent-based printing plant [18, UBA Germany, 2003].

For packaging gravure, total emissions of 10 % of the total input can be achieved (fugitive and emissions after treatment). However, this requires a high level of emission reduction measures.



A recent report [77, VROM, 2004] showed VOC emissions from flexible packing plants using good practice to be in the order of 7.5 to 12.5 % of the reference emission (calculated according to Annex VII to Directive 2010/75/EU (IED)). Older plants that have connected only the more concentrated VOC sources to waste gas treatment achieve 10 – 25 % of the reference emission. Lower values may be associated with the extensive use of solvent-free products. Similarly, some plants without abatement equipment can achieve less than 25 % of the reference emission, but as a consequence, not many of these will use more than 200 tonnes of solvent per year.

In total, 29 different emission sources were distinguished. These include not only sources for fugitive emissions but also some sources for waste gas emissions. Distinction was made between four different groups of emission sources: press room (P), incineration (O for 'oxidiser'), cleaning (C) and ink preparation (I).

Table 12.14 below gives, for many sources, a typical emission value, possible reduction measures for that source and a typical emission value after the reduction measures have been taken. The following points should be borne in mind:

- 'Typical' emission values are provided to give an impression of the order of magnitude. The emission is expressed as a percentage of the solvent consumption of the plant. Actual emissions values may vary widely.
- 'n.a.' means that no typical emission value can be given. Emissions from sources such as 'defects in bypasses' or 'solvent content water-based products' obviously vary enormously from plant to plant.
- 'Very small' means that the total emissions of all the 'very small' sources may be less than 1 % of the solvent consumption.
- 'Negligible' means that the emission is either zero or an order of magnitude smaller than the 'small' emissions. Their total volume is smaller than the margin of error in the larger emissions.

Table 12.14: Reduction of fugitive emissions from flexible packaging printing

Group	Activity or source	Typical emission	Possible reduction measures	After reduction
P	Evaporation from the ink fountains during production	5 %	1. Adequate coverage of the ink fountains 2. Use chamber doctor blades 3. Encapsulation of varnishing or lamination units 4. Use of adhesives with reduced solvent content (see relevant techniques in Section <del>Error! Reference source not found.</del> ) 5. Floor extraction through dryers 6. Floor extraction sent to incinerator (see Section <del>Error! Reference source not found.</del> )	<2.5 %
	Evaporation from open viscosity adjustment units	Very small	<del>None</del> Encapsulation	Negligible Very small
	Leaking dryers through defects or dryer pressure higher than atmospheric	n.a.	Proper maintenance, correct operation, periodic checks (see Section 17.10.2.6)	Negligible
	Defects in the bypass of the dryers (waste gases sent to atmosphere rather than to the incinerator)	n.a.	Give priority, proper maintenance, correct operation, periodic checks, instruction for manual operation if possible, speedy repairs (see Section 12.4.3.4)	n.a.
	Waste gas emissions from presses when these are filled with ink, but not yet printing	Negligible NA	<del>None</del> Automatic closure of bypass before make ready speed is reached	Negligible
	Waste gas emissions from presses when these are printing at minimum speed	0.1 %	<del>None</del>	0.1 %
	Waste gas emissions from presses in the case of defects to production machines	Very small	<del>None</del>	Very small
	Waste gas emissions from presses when printing at make-ready speed. (30–60 m/min)	3–8 %	Automatic closure of bypass before make-ready speed is reached (see Section <del>Error! Reference source not found.</del> )	Negligible Very small
	Cleaning floors	1 %	1. Prevention of soiling 2. Use of squeezable sweeps 3. Use non-volatile cleaning agents (see Sections 17.9 and 17.9.6)	Very small
	Evaporation from open drums	Negligible Very small	Keep closed as much as possible (see Section 17.2.2)	Negligible
O	Residual solvent packaging materials for food	Very small Negligible	<del>None</del>	Very small Negligible
	Residual solvent in printed materials that are not packaging for food	3–10 %	Improve drying	0.1 % <0.1 %
	Emissions from the incinerator	0.5–1.5 %	(May increase if additional solvent laden air stream are sent to incinerator)	0.5–1.5 %
	Defects in the incinerator causing waste gases to be sent to the air	n.a. (0.4 % of input per defect day)	High priority: proper maintenance, correct operation, periodic check, instruction for manual operation if possible, speedy repairs (Section <del>Error! Reference source not found.</del> ) Equip with computer techniques, connect to supplier (see Section 0)	Very small
	The use of solvent-based inks, varnishes and adhesives on machines not attached to the incinerator	n.a.	Connect to incinerator at times when incinerator has enough capacity (see Section 17.10.1.1.1)	<del>n.a.</del> 0.5–1.5 %
The use of solvent-based inks, varnishes and adhesives on dryers not attached to the incinerator	n.a.	Refrain from using these dryers for solvent-based inks Connect to incinerator at times when incinerator has enough capacity (see Section 17.10.1.1.1)	<del>n.a.</del> 0.5–1.5 %	

Group	Activity or source	Typical emission	Possible reduction measures	After reduction
	Solvent content of water based products (inks contain approx. 5 % solvent, varnishes and adhesives may be fully solvent free)	n.a.	Priority: Use water based products with solvent content as low as possible. Otherwise: none (see relevant techniques in Section <del>Error!</del> <del>Reference source not found.</del> )	n.a.
C	Drying process and ventilation in automatic washing machines using solvents	5 %	1. Ventilation to incinerator (Section 2. Use non-volatile cleaning agents (see Sections 17.9 and 17.9.6)	Negligible 0.5-1.5%
	Evaporation during manual cleaning operations - Cleaning and drying by hand after washing automatically - Cleaning with machines other than automatic washing machines -Evaporation from open drums (solvent, waste etc)	1 %	1. Prevent useless evaporation 2. Prevent cleaning and drying by hand after washing automatically 3. Use automatic washing machine as much as possible 4. Use non-volatile cleaning agents as much as possible 5. In press room, prevent contamination of objects that cannot be cleaned in washing machine as much as possible 6. In-depth cleaning of anilox rollers and cylinders with solvent-free methods (see Sections 17.9 and 17.9.6)	0.5 %
	Cleaning and drying by hand after washing automatically	Included	See manual cleaning (see Sections 17.9 and 17.9.6)	Included
	Cleaning with machines other than automatic washing machines	Included	See manual cleaning (see Sections 17.9 and 17.9.6)	Included
	Cleaning of the floors	Included	1. Prevention of soiling 2. Use of squeezable sweeps 3. Use of non-volatile cleaning agents (see Sections 17.9 and 17.9.6)	Included
	Evaporation from open drums (solvent, waste, etc.)	Included	Keep closed	Included
I	Evaporation resulting from the mixing of inks	Very small	Automatic ink mixing systems, drum close to nozzles, quickly close drums after filling (see Sections 0 and 17.2.2)	Very small
	Evaporation resulting from making colour tests	Negligible	None	Negligible
	Cleaning of the floors and other cleaning	1 %	1. Prevention of soiling 2. Use of squeezable sweeps 3. Use of non-volatile cleaning agents (see Sections 17.9 and 17.9.6)	0.5 %
	Evaporation losses from tanks	Negligible	None	Negligible
	Evaporation from open drums	Very small	Keep closed (see Section 17.2.2)	Very small Negligible

Source: 77, VROM , 2004, updated by [197, FPE, 2017]

The emissions caused by defects in driers, bypasses or in the incinerator itself may be considerable. The same is true for machines and driers not attached to the incinerator and the solvent content of water-based inks. No typical emission values are given, but the total of the emissions from these sources may easily be several per cent of the annual solvent consumption. It can be seen that the total of the emissions from all the other sources may vary enormously. If none of the reduction measures mentioned in Table 12.14 are applied, this total may amount to well over 25 % of solvent consumption. If all possible reduction measures are applied, the total of these emissions may be well below 15 % of solvent consumption.

Allowing for several per cent of emissions due to defects and the solvent content of water-based inks, the total emissions can be expected to vary between 30 and 10 % in most plants.

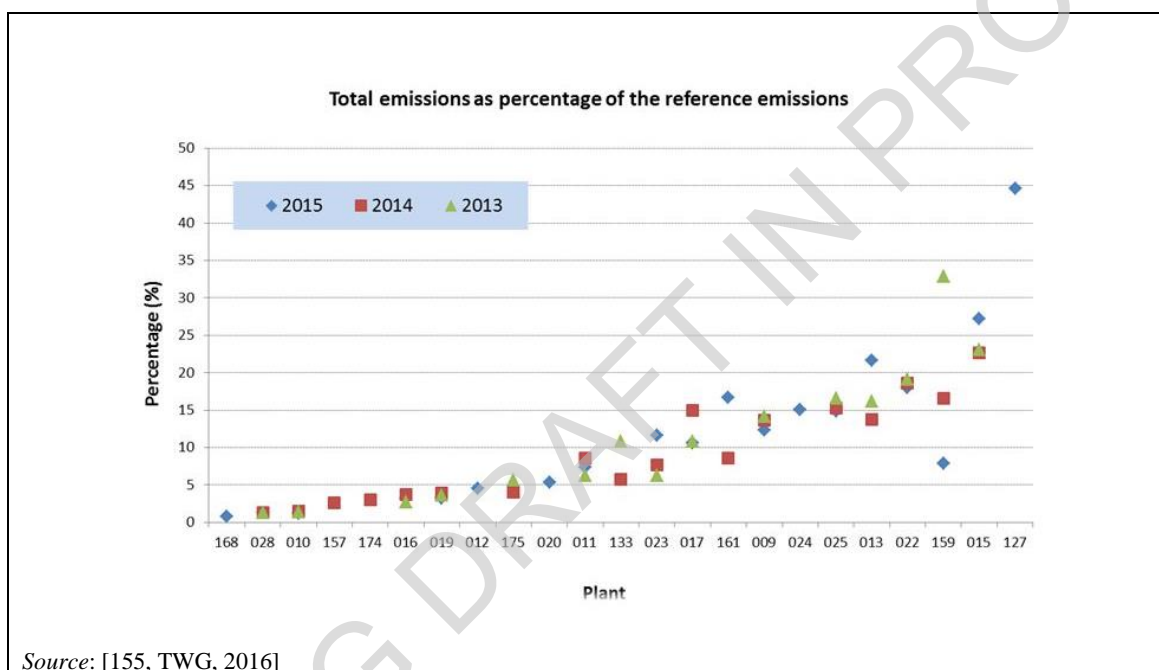
In order to attain low total emission values ~~lower than 10% of solvent consumption~~, it is necessary to carry out all or most of the following:

- prevent defects to incinerator, bypasses, dryers, etc.

- send waste gases from the dryers to the incinerator ~~both~~ automatically ~~and~~ before make-ready press speed is reached
- connect the ventilation exhaust of the automatic washing machines to the incinerator)
- reduce emissions due to evaporation from ink fountains during production
- avoid the use of solvent-based products on machines not connected to the abatement equipment
- reduce the residual solvent in printed materials not intended to be used as packaging for food
- reduce the use of volatile solvents for cleaning floors (see Sections 17.9 and 17.9.6).

**12.3.2.1.1 Total VOC emissions**

Reported values of specific VOC emissions expressed as a percentage of the reference emissions are presented in Figure 12.3. Reference emissions are calculated according to Annex VII (part 5) to Directive 2010/75/EU (IED).



Source: [155, TWG, 2016]

**Figure 12.3: Reported values of total VOC emissions expressed as percentage of the reference emissions for the period 2013–2015**

The basic parameters for the outline and production features of the reporting plants are presented in Table 12.15 below. An explanation of abbreviations used for the packaging and non-publication gravure data is provided in Table 12.16.

**Table 12.15: Main production and contextual information of installations reporting VOC emission data**

Installation	Units type	Abatement system	Machines encapsulation	Production hall outline	Ink piping	Ink type	Press washing system	Cleaning	Machines connected to abatement
168	4FI	RTO/2 WS/CA	EN	EN-T	Auto	SL	Auto	SB	4/4
028	3PG/3FI/1L/1PL	RTO	EN	EN-nT	NI	SB	Auto-man	SB	6/7
010	1FI/2PG	2CO/RTO	EN	EN-T	NI	SB	Auto-man	SB	3/3
157	3FI/2L	RTO	NI	NI	NI	NI	NI	NI	NI
174	2PG/1L	RTO	EN	EN-T	Auto	2SB/1SL	Man	SB	3/3
016	2PG/4L/1FI	AACZ/TO	4EN-4OP	EN-T	Auto	SB	2 auto/6 man	SB/WB	7/7+W
019	3PG	2RTO	OP	EN-nT	Pump	SB	Man	SB	3/3+W
012	4FL/5PG/2PL/3V/5L/1LC	4RTO/AACZ	4EN/16OP	EN-nT	P-auto	17SB/1WB/2UV	Man	17SB/3WB	18/20
175	4FI/2L	RTO/CO	OP	EN-nT	Auto	4SB/2SL	Auto-man	SB	5/6
020	8PG	AACZ	OP	EN-nT		SB	Man	DI	8/8
011	7PG	RTO	OP	EN-nT	Pump	2SB/5WB	Man	2SB/5WB	2SB
133	2PL/1PG/1FI/1L	RTO/TO	7OP/1EN	NI	NI	SB/2SL	Man	SB	5/5
023	2FI/3PG	AACZ		EN-T	Auto	SB	Auto	SB	5/5
017	4PG	AACZ	OP	pEN	NI	3SB/1SL	Man	SB	4/4
161	2PG/1FI/2PL	TO	OP	EN-nT	Pump	4SB/1FIUV	Man	SB	5/5+W
009	3PG/3V/2L	2RTO	3OP/5EN	EN-nT	NI	SB	Man	SB	8/8
024	2PG/2FI/4L	SRN	OP	EN-T	Auto	SB	Auto	SB	6/8
025	3L/2EPL/2PL/4P	AACZ	3EN/8OP	EN-nT	Pump	SB	Man	SB	11/11
013	5PG	RTO-3	OP	EN-T	Cont	SB	Auto	SB	5/5
022	4PG/4L	AACZ	OP	EN-T	Auto	SB	3 auto/5 man	SB	8/8
159	9PL/1FI/3IJ	RTO	12OP/1EN	En-nT	NI	SB	Man	SB	10/10
015	2PG	RTO	OP	En-T	NI	SB	Man	SB	2/2
127	2FI/1PG	RTO	EN	pEN	Auto	SB	Man	SB	3/3
008	2FL/1L	TO	EN	NI	NI	SB	NI	NI	3/3

NB: NI = No information provided.  
Source: 155, TWG, 2016

**Table 12.16: Explanation of used abbreviations for the packaging and non-publication gravure data**

Unit type		Ink type – cleaning material type	
FI	Flexography	SB	Solvent-based
PG	Packaging gravure	SL	Solvent-less
L	Lamination	WB	Water-based
PL	Printing & Lamination	UV	UV-cured
IJ	Ink jet printing	DI	Dry ice
V	Varnishing	Machines encapsulation / production hall layout	
LC	Lamination & Coating	OP	Open
		EN	Enclosed
		EN-nT	Enclosed with air extraction but without subsequent treatment
		EN-T	Enclosed with air extraction and subsequent treatment

Although the reported values are strongly affected by specific circumstances (e.g. VOC abatement system breakdown), more than half of reported values are below 10 %. Some basic statistical figures are presented in Table 12.17.

**Table 12.17: Statistical parameters of reported values of total VOC emissions (as a percentage of reference emissions) from flexographic installations**

Parameter	2015	2014	2013	Average (2013–2015)
<b>Average</b>	12.0	9.2	14.2	11.4
<b>Median</b>	10.7	8.1	10.8	8.3
<b>25<sup>th</sup> percentile</b>	3.9	3.8	5.2	3.4
<b>75<sup>th</sup> percentile</b>	15.9	14.7	17.2	16.4

Source: 155, TWG, 2016

Lower values were reported from installations applying thermal VOC destruction abatement techniques while slightly higher values reported from installations applying solvent recovery techniques.

The statistical parameters of the reported data according to the abatement method applied are presented in Table 12.18

**Table 12.18: Statistical parameters of reported values of total VOC emissions (as a percentage of reference emissions) from flexographic installations in relation to the applied abatement technique**

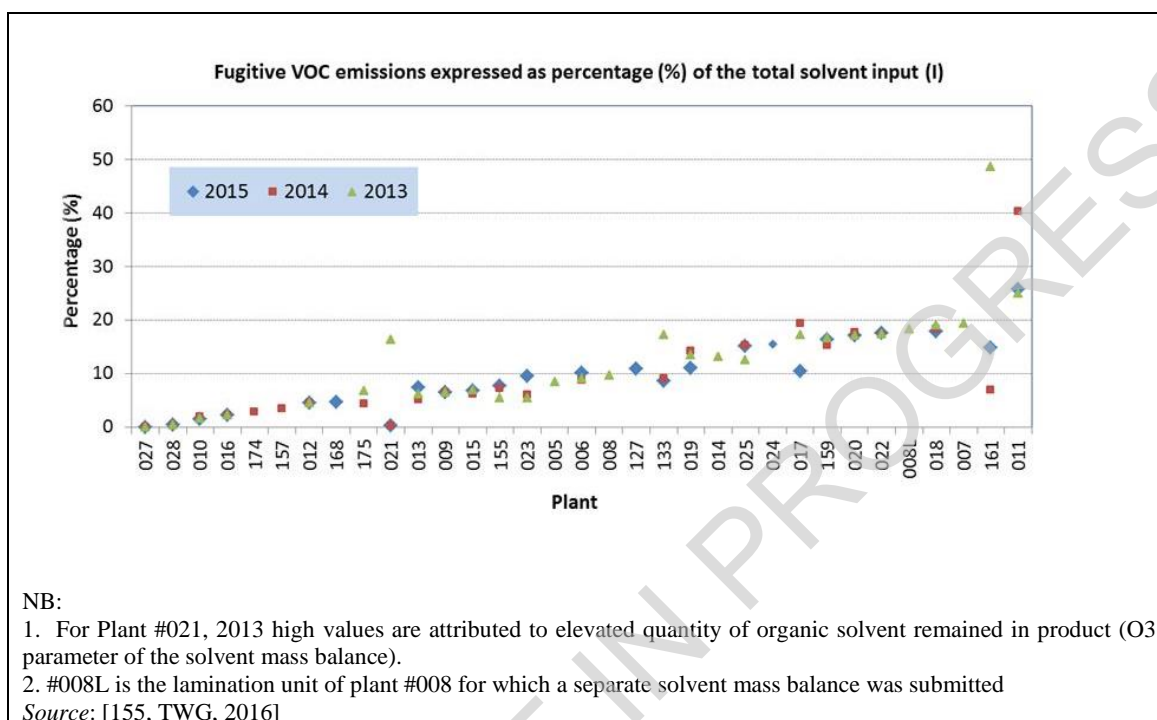
Parameter	2015		2014		2013		Average (2013–2015)	
	RTO	Recovery	RTO	Recovery	RTO	Recovery	RTO	Recovery
<b>Average</b>	11.7	12.6	7.8	14.1	10.7	13.2	10.1	12.5
<b>Median</b>	7.4	13.3	4.9	15.1	6.2	13.7	4.9	13.6
<b>25<sup>th</sup> percentile</b>	3.2	10.9	3.2	13.1	3.2	9.7	3.0	9.4
<b>75<sup>th</sup> percentile</b>	16.7	15.0	12.4	16.1	15.2	17.2	13.4	15.5

Source: 155, TWG., 2016

Most of the installations use solvent-based inks while the use of solvent-free inks is reported for a small number of machines.

### 12.3.2.1.2 Fugitive VOC emissions

The reported values for fugitive VOC emissions expressed as a percentage of the total solvent input are presented in Figure 12.4



**Figure 12.4: Reported values of fugitive VOC emissions expressed as a percentage of the total solvent input for the reference period 2013–2015**

Almost all of the reported values for fugitive emissions are below the IED limit value of 20 % of the total solvent input and more than the half of reported values are below 10 % of the total solvent input.

In most of plants, the production hall is totally enclosed and the air from it is extracted with or without subsequent treatment (see Table 12.15). Machine parts cleaning is mainly solvent-based and there is a significant number of installations that have installed a dedicated cleaning machine and have connected its extraction to the abatement system.

The main reported techniques for the minimisation of fugitive emissions are:

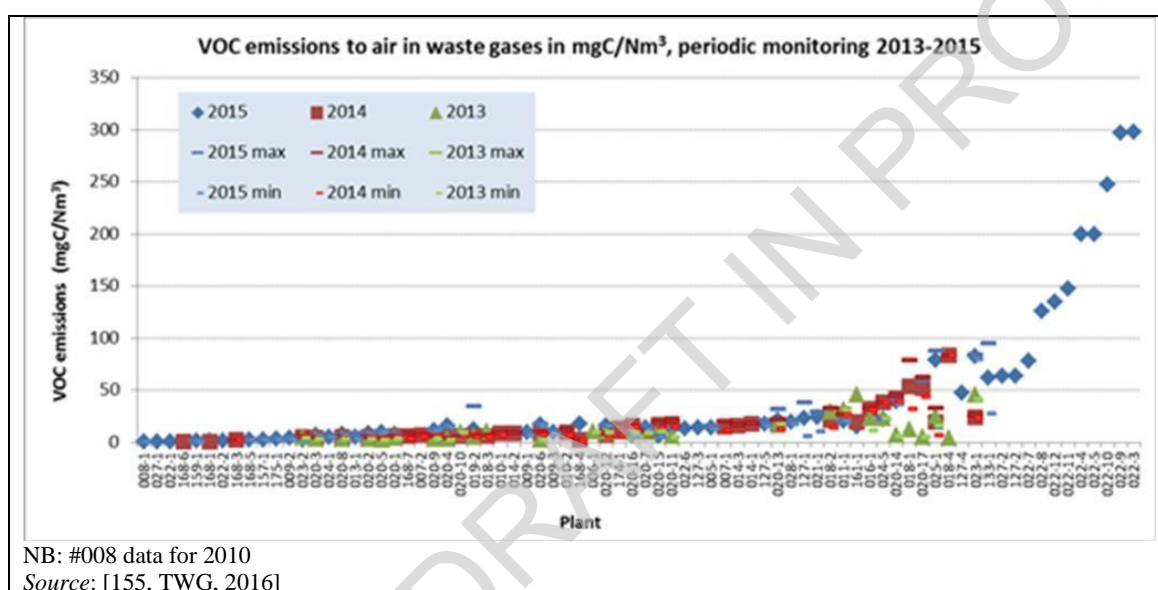
- safe storage of hazardous substances and measures to prevent unplanned releases;
- handling and use of hazardous materials;
- air extraction from drying processes;
- enclosed application zones with air extraction;
- hall ventilation partly used as dryer input, treated in RTO;
- air recirculation in dryers;
- overpressure management with installed waste air pipes to minimise leakages caused by overpressure;
- ink management techniques that include automatic ink mixing system and management of ink residues;
- automatic hardener dosing using enclosed piping system (two-component systems);
- air extraction from washing machines, adhesive mixing and inks mixing area;

- automatic parts cleaning machine (solvent-based, connected with peak/trough smoothing and common waste gas extraction for treatment in RTO);
- solvent-free adhesives (hot melts);
- ultrasonic cleaning machine for anilox rollers.

### 12.3.2.1.3 VOC emissions in waste gases

The majority of reported data concerns periodic monitoring of VOC emissions for the abatement installation with measurement periodicities that vary from four times a year up to once every three years. At the majority of installations with periodic monitoring, annual measurements (once every year) occur.

The reported values for periodic monitoring of VOC emissions expressed in  $\text{mg C/Nm}^3$  are presented in Figure 12.5.



**Figure 12.5: VOC emissions to air in waste gases ( $\text{mg C/Nm}^3$ ) from flexographic installations - Periodic monitoring for the period 2013–2015**

Some basic statistical parameters of the reported values for VOC emission values from periodic monitoring are presented in Table 12.19.

**Table 12.19: Basic statistical parameters of the reported values for TOC concentration values from periodic monitoring**

Parameter	2015	2014	2013
Number of values	59	42	30
Average	45	16	13
Median	14	9	10
25 <sup>th</sup> percentile	7	6	4
75 <sup>th</sup> percentile	51	19	16

Source: [155, TWG, 2016]

The reported values underline the efficiency of the applied end-of-pipe abatement techniques which on average achieve low TOC concentration values.



A small number of installations reported data for continuous monitoring of VOC emissions in waste gases. These data are presented in Figure 12.6.

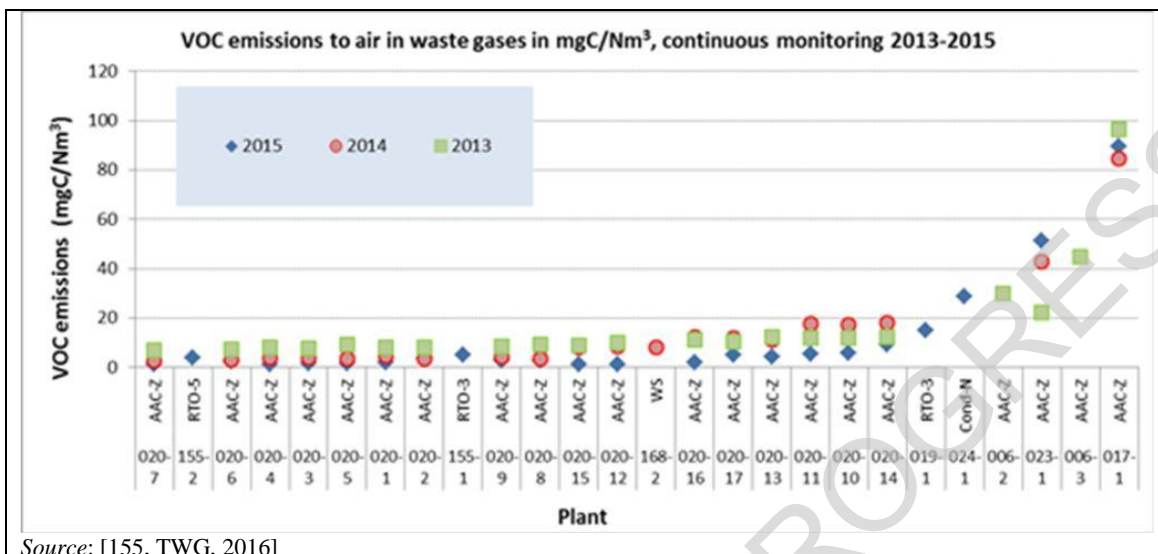


Figure 12.6: Measured concentrations of VOC emissions to air in waste gases (mg C/Nm<sup>3</sup>) from flexographic installations - Continuous monitoring for the period 2013–2015

### 12.3.2.2 NO<sub>x</sub> and CO emissions

Reported values for NO<sub>x</sub> and CO concentrations are presented in Figure 12.7.

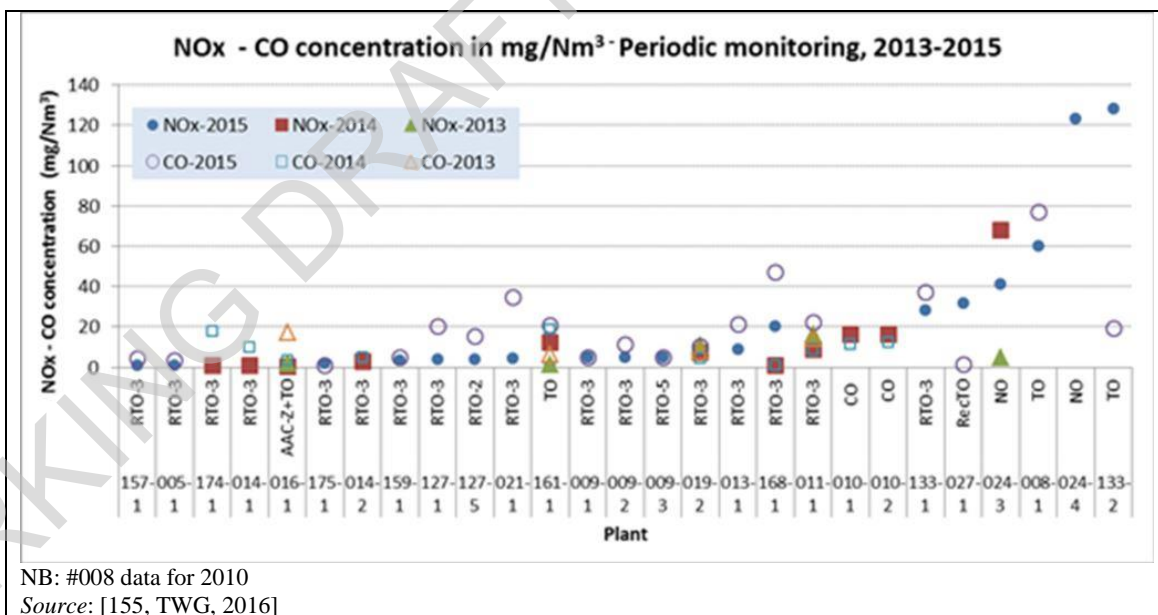


Figure 12.7: Measured concentrations of nitrogen oxides (NO<sub>x</sub>) and carbon monoxide (CO) (mg/Nm<sup>3</sup>) in waste gases from flexographic installations - Periodic monitoring for the period 2013–2015

The reported values demonstrate that it is possible to achieve low NO<sub>x</sub> levels with no significant offset for the relevant CO concentration values. In general for both parameters values below 60 mg/Nm<sup>3</sup> were reported.

The emissions caused by defects in driers, bypasses or in the incinerator itself may be considerable. The same is true for machines and driers not attached to the incinerator and the solvent content of water based inks. No typical emission values are given, but the total of the emissions from these sources may easily be several per cent of the annual solvent consumption.

It can be seen that the total of the emissions from all the other sources may vary enormously. If none of the reduction measures mentioned in **Error! Reference source not found.** are applied, this total may amount to well over 25 % of solvent consumption. If all possible reduction measures are applied, the total of these emissions may be well below 10 % of solvent consumption.

Allowing for several per cent of emissions due to defects and the solvent content of water based inks, the total emissions can be expected to vary between 30 and 10 % in most plants.

### **Inks**

For water based inks, 0.5–1.0 % ammonia emissions per kg ink input can be expected. On average, water based inks contain 0–10 % organic solvent (ethanol or IPA) which will, in the end, be emitted [18, UBA Germany, 2003].

There are no emissions to air from UV inks.

### **Lamination and varnishing**

When using solvent based (SB) materials, the emissions from these processes are higher than from printing. With solvent based adhesives, a large amount of air has to be moved through the drier to keep the solvent/air ratio well below the lower explosive limit (LEL) [4, Intergraf and EGF, 1999] [38, TWG, 2004].

Increasingly 2 component, solvent free adhesives and water based varnishes are used for lamination of plastic foil and varnishing of aluminium respectively. Water based adhesives are often used to adhere paper to aluminium. Where water based inks mostly still contain some solvent, water based adhesives and varnishes are generally solvent free.

### **Cleaning**

Fugitive solvent emissions arise from cleaning where the quantity depends on the handling.

### **Waste gas treatment**

Modern regenerative incinerators can work without the addition of fuel (autothermic operation) when the solvent concentration in the air to be treated is  $>1 \text{ g/m}^3$ . At higher concentrations, the incinerator may produce excess heat, which may be recovered and used in production processes. In flexo and packaging gravure plants where the airflow has been optimised, and a large amount of the work is with 100 % coverage (such as white ink, adhesives and varnishes) concentrations of 4 to 6  $\text{g/m}^3$  are attainable, otherwise lower concentrations are found [38, TWG, 2004].

With incineration, emission levels of  $<100 \text{ C/Nm}^3$  can be achieved and often levels of 20–50  $\text{C/Nm}^3$ , see Section 17.10.5.2 [38, TWG, 2004, 78, TWG, 2005]

Adsorption is also applied, although to a lesser extent, see Section 0. Adsorption can achieve a removal efficiency of up to 99 % in publication gravure (see Section 13.3.3), although this is not usual as it requires a high energy input in regeneration of the absorbent. In the clean gas, concentrations of  $<20 \text{ mg/m}^3$  are achieved. The hot steam desorption generates about 3–6  $\text{m}^3$  per kg of recovered solvent. In flexible packaging, solvent recovery through adsorption to activated carbon is also applied; frequently in Italy, rarely elsewhere. Where solvent recovery is applied, solvent consumption is limited as far as technically possible to ethyl acetate, in order to reduce the size of the adsorption unit, reduce dehydration problems and reduce the occurrence of azeotropic mixtures of ethylacetate with ethanol and MEK. Hot steam desorption is used less and less in flexible packaging, and currently inert gas desorption is usual. Recovery rates are

generally 95 to 95.5 %, with a waste gas concentration of 50 to 150 mgC/m<sup>3</sup>. [14, DFIU and IFARE, 2002] [4, Intergraf and EGF, 1999, 78, TWG, 2005]

### 12.3.2.3 Waste

[78, TWG, 2005], [155, TWG 2016] [155, TWG, 2016]

#### Printing substrate

Printing substrate is wasted when starting a new printing job and also arises from misprints because of defects and when the edge of the printed web roll requires trimming. The quantity depends on the product produced, ~~however it often accounts for 10 % of the final product in weight~~ [18, UBA Germany, 2003] [38, TWG, 2004].

#### Ink

Ink losses arise from three areas [4, Intergraf and EGF, 1999]:

- The amount of ink prepared always exceeds the need to avoid presses running out of ink.
- Ink supplied to the inking unit, but not used, is stored and later used on a repeat job for the same client. Most plants have a large stock of these readymade inks waiting for repeat jobs. Periodically, inks that are not expected to be used again are removed.
- The mixing of the ink results in the wrong colour. To correct this mistake, more ink has to be added and, as a result, too much ink is prepared.

Surplus inks are disposed of as waste, or alternatively are distilled in-house. Their solvent content is then recovered and used for cleaning purposes; the ink sludge is disposed of as waste.

However, modern practice with computerised colour-matching systems enables better first time quality resulting in very little ink wastage and minimal leftover batches, which can be used again in slightly different colours (see Section 17.6.3.1). In situations where no computerised systems for mixing the right colour are applied, some 10–20 % of the ink purchased ends up as waste. Where computerised systems are used, the amount of waste ink is reduced by at least 25–75 % [18, UBA Germany, 2003] [38, TWG, 2004].

#### Varnish and ink sludge

Solvent, ink and varnish sludges are resulted into the production process and often from the distillation process for the recovery of solvent content which can be reused for cleaning processes. When there is not a previous distillation step, significant solvent contents have been reported (up to 70 %).

#### Cleaning

Dirty wipes containing solvents, absorbents, filters, wiping cloths, protective clothing, dirty cleaning mixtures of water and solvent, and ink residues stem from interim cleaning. When the cleaning agents are distilled, the resulting waste, i.e. ink sludge, is far less than without recovery [18, UBA Germany, 2003].

When cleaning is done ~~without using solvents~~, the waste water might be treated and discharged. Cleaning solutions with solvents are normally treated as hazardous waste [4, Intergraf and EGF, 1999] [38, TWG, 2004].

Cleaning agents can be successfully recovered by distillation.

#### Others

Other wastes are, for example [4, Intergraf and EGF, 1999] [38, TWG, 2004]:

- photopolymer and rubber printing plates: the steel, polyester or aluminium sleeves are reused repeatedly: the polyester or rubber materials are glued to these;
- non-returnable metal containers;

- reel cores;
- glue and adhesive wastes;
- film wastes.

### 12.3.2.3.1 Waste water

Waste water from water-based ink processes can be treated and disposed of to the sewerage system or disposed of as waste. The total amount of waste water is highly dependent on the working methods, and on average 2–3 m<sup>3</sup>/t ink is used and discharged, mainly from interim cleaning and cleaning the machinery after a job. If treated, treatment, the water may be reused and the sludge disposed of as waste [1, INTERGRAF and EGF, 1999] [38, TWG, 2004]. The characteristics of this waste water before and after treatment are shown in Table 12.20. Copper is not present to the extent shown in Table 12.20 in inks, and is likely to come from the paper (see Section 11.3.2.4) [38, TWG, 2004].

**Table 12.20: Characteristics of waste water from water-based ink processes**

<b>Contaminant</b>	<b>Before treatment (mg/l)</b>	<b>After treatment (mg/l)</b>
<b>AOX</b>	1500	1
<b>Cu</b>	20	
<b>Hydrocarbons</b>	1 000–5 000	10
<b>COD</b>	1 000	200
<i>Source: [18, UBA Germany, 2003]</i>		

The amount of ink sludge resulting from the waste water treatment differs depending on the treatment applied. Treatments such as coagulation and flocculation, which are most commonly applied, result in high quantities of sludge compared to ultrafiltration, for example [18, UBA Germany, 2003].

A study by the TWG identified the main parameters and other substances of interest that may be discharged in waste waters (including those mentioned above) and therefore to be considered for the data collection<sup>27</sup>. These are identified in Table 3.25 below, with the results of the data gathering exercise. The sources of waste waters are diverse, with various combinations of treatment and discharge type. The main concern for this sector is possible emissions from gravure cylinder preparation; however, only one data set was submitted, showing low values. COD values varied significantly according to the source.

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<sup>27</sup> COM working document EIPPCB 09/06/2016: Assessment of Technical Working Group (TWG) data submitted on metals and other emissions to water for their consideration as Key Environmental Issues for installations carrying out IED Annex 1 6.7 activities

Table 12.21: Results of data gathering exercise for flexography and non-publication gravure

Plant number <sup>(1)</sup>	WWTF	Source	Discharge type	COD	TOC	Cu	Cr <sub>total</sub>	Cr(VI)	Zn
006	NI	Mainly from distillation	nd	1933	ND	ND	ND	ND	ND
133	NI	Not process	Reused	22.5	ND	ND	ND	ND	ND
023	NI	Cooling (evap) system for solvent recovery	NI	60	NI	NI	NI	NI	NI
025	None	Cooling	Direct	16	NI	0.035	0 <sup>(3)</sup>	NI	NI
025(b) <sup>(2)</sup>	None	Cleaning	Indirect	5	NI	NI	NI	NI	NI
020	Combined	Steam from regeneration of activated carbon	Indirect	807	276	NI	NI	NI	NI
022	Dedicated	Gravure roller processing	Indirect	NI	NI	0.01	0.01	0.01	0.12
022(b) <sup>(2)</sup>	NI	Cooling?	NI	5	NI	NI	NI	NI	NI
024	None	nd	Indirect	23	NI	0.05	NI	0.001	0.43

NB:

NI = No information provided.

<sup>(1)</sup> Plants in order of WWTF, gravure roller processing and discharge type.<sup>(2)</sup> (b) indicates second discharge point, neither with data relating to process sources.<sup>(3)</sup> 0 as reported, no LoD given.

No Ni results reported.

Source: [155, TWG, 2016]

## 12.4 Techniques to consider in the determination of BAT for flexography and non-publication gravure

[78, TWG, 2005]

In Chapter 17, techniques are discussed which might also be applicable to flexography and packaging gravure. In Table 12.22, the general techniques relevant for flexography and packaging gravure are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

**Table 12.22: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### 12.4.1 Solvent mass balance for gravure and flexographic printing systems

[198, DE, 2017]

*Work in progress – TWG please provide additional information*

#### Description

The following procedure is a guide for the compilation of solvent mass balances (SMB) for gravure and flexographic printing systems.

#### 1. Determination of fugitive emission F

Fugitive emissions F can be calculated as follows:

$$F = I1 - O1.1 - O5 - O6 - O7 - O8$$

$$\text{(or: } F = I1 - (O1.1 + O5) - O6 - O7 - O8)$$

(O1.1 + O5) represents the amount of VOCs in the raw gas of the waste gas cleaning system. This can be determined by the plant of an operational flame ionisation detector for continuous detection of total C mass concentration in conjunction with a continuous detection of the volume flow in the raw gas:

$$(O1.1 + O5) = cC_{tot} * 10^{-6} * fS * VR * tR \text{ in kg/yr}$$

where

(O1.1 + O5) = VOC amount in raw gas in kg/yr;

cC<sub>tot</sub> = average total carbon concentration in raw gas in mg/Nm<sup>3</sup>;

fS = conversion factor of cC<sub>tot</sub> to solvent (VOC);

VR = average waste gas volume flow of the crude gas under normal conditions in Nm<sup>3</sup>/h and dry;

tR = operating time of the waste gas cleaning system in h/yr.

The average annual raw gas concentration cC<sub>tot</sub> must be formed from all measured values. To convert the total carbon concentration cC<sub>tot</sub> to the substance-specific solvent concentration (cVOC) to be monitored, the latter must be multiplied by the conversion factor fS. This conversion factor fS results from the quotient of the molar mass and the carbon fraction of the solvent used.

The exhaust air volume flow has to be determined continuously using a volumetric flow measurement. The average exhaust gas volume flow VR must be determined from all measured values.

In justified individual cases, alternatively the raw gas quantity may be determined from the measured lower explosive level (LEL) values of the concentration measuring devices or by means of additional built-in IR sensors.

The measurement errors caused by the sensitivity of the concentration measuring devices to the different solvents must be corrected by calculating an average value for the solvent mixture used with which the measured LEL value is interpreted. The solvents used must be proportionally weighted and the measured LEL value should be interpreted with this correction factor.

The average raw gas mass flow in Nm<sup>3</sup>/h is calculated as the quotient of the sum of all determined raw gas mass flows and the number of all investigations in the reference period.

If different solvents are used in the printing process and these cause different cross-sensitivity to the sensors, detectors with small differences in cross-sensitivity are to be used. For example, a sensor calibrated to ethyl acetate can indicate up to 50 % too high a value when using pure ethanol as a solvent. This would lead to too little concentration in the normal operation. At an actual ethanol concentration of 30 % LEL, 45 % LEL would be measured in this case, resulting in an admixture of actually unnecessary fresh air, e.g. to reach the set point of 35 % LEL (this is a tried-and-tested set point because it still has sufficient distance to the warning and shut-off points).

## 2. Determination of the fraction of the amount destroyed in waste gas abatement system (O5)

In order to determine the quantity of fugitive emissions F, if not according to 1, the knowledge of the quantity O5 is required, i.e. the amount of solvents destroyed in a waste gas abatement system:

$$F = I1 - O1.1 - O5 - O6 - O7 - O8$$

The amount of solvent destroyed by waste gas cleaning (O5) can be determined by means of the abatement efficiency ('efficiency', better AR = removal efficiency) of the oxidative waste gas cleaning by means of the following relationship:

$$O_5 = \left( \frac{O_{1.1}}{1 - A_R} \right) - O_{1.1}$$

A<sub>R</sub> - Removal efficiency of thermal oxidation  
O<sub>1.1</sub> - Emissions from captured and treated waste gases

$$A_R = \frac{\text{concentration of raw gas} - \text{concentration of clean gas}}{\text{concentration of raw gas}}$$

Decisive here are the resilient representative determination of O1.1 as well as the removal efficiency. For this purpose, parallel measurements of the total C mass concentration of the raw and clean gas over a longer period of time may be necessary.

### 3. BAT for determining the emissions from captured and treated waste gases (O1.1)

The VOC emissions contained in the clean gas of a waste gas cleaning system (O1.1) are calculated according to the following equation:

$$O1.1 = cC_{tot} * 10^{-6} * fS * VR * tR \text{ in kg/yr}$$

where

O1.1 = VOC mass flow in the clean gas in kg/yr;

cC<sub>tot</sub> = total carbon concentration in the clean gas in mg/Nm<sup>3</sup>;

fS = factor for conversion from cC<sub>tot</sub> to VOC;

VR = average waste gas flow under normal conditions in Nm<sup>3</sup>/h and dry;

tR = operation time of the waste gas cleaning unit in h/yr.

The average total carbon value (CC<sub>tot</sub>) of the last emission measurement shall be used as the mass concentration. A continuous determination of the total C mass concentration in combination with the continuous determination of the waste gas volume flow would be ideal. Otherwise, representative mass concentrations of clean gas are to be determined during the measurement of the emission. This may possibly also require the measurement over a longer period of time (e.g. working day). The mass concentration of the solvents (solvent mixtures) used should be converted using the factor fS. The conversion factor fS is to be formed from the quotient of the molar mass and the carbon content of the solvent used.

The exhaust air volume flow has to be determined continuously using a volumetric flow measurement. The average waste gas volume flow has to be determined from all measured values. Alternatively, it is permissible to determine the volume flow via the frequency converter of the raw gas fan. Alternatively, the emissions in the captured treated waste gas can also be measured directly using flame ionisation detector (FID) or flame temperature analysis (FTA) devices. From the individual values of mass concentration, the average annual mean value shall be determined according to the method described above.

#### 12.4.2 Material-based techniques

##### Replacement of conventional solvent-based inks (substitution)

###### ~~Conventional solvent-based inks~~

~~Deleted – not a BAT candidate~~

~~Conventional techniques have been deleted if they can no longer be considered BAT.~~

~~This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumptions or emissions.~~

~~**Description:** See Section **Error! Reference source not found...** The most common main solvents are ethanol, ethyl acetate and mixtures of these two, where ethanol is used more in flexo and ethyl acetate more in gravure. Other solvents like isopropanol or MEK may also be used as the main solvent. In addition, many different solvents may occur in small quantities for adjustments to, for instance, drying speed and viscosity or as content of the ink as bought. Today, simplification and standardisation has led to the reduction of the number of different solvents, but in the mid 1990s, up to twenty different solvents could be found in one flexible packaging plant.~~

~~**Achieved environmental benefits:** No information submitted.~~



**Cross-media effects:** Over 90 % of the solvents consumed can be emitted.

**Operational data:** The exact composition also depends on the quality requirements for the packaging material and the resistances that it must have, for example, resistance to acids, high temperatures, water, alcohol, barrier properties such as odour, impermeability for light, etc.

Waste gas treatment is generally used to remove VOCs.

**Applicability:** No information submitted.

**Economics:** No information submitted.

**Driving forces for implementation:** No information submitted.

**Example plants:** No information submitted.

**Reference literature:** [18, UBA Germany, 2003] [4, Intergraf and EGF, 1999] [8, Nordie Council of Ministers, 1998] [9, VITO, 1998] [38, TWG, 2004] [78, TWG, 2005]

### 12.4.2.1 UV curing alternatives

#### Description

UV curing inks do not contain organic solvents. Curing is achieved by UV radiation. See also Section 17.7.2.4

#### Achieved environmental benefits

In printing processes where inks based on volatile solvents are used, a significant reduction in solvent emissions can be achieved.

#### Cross-media effects

In some circumstances, the energy consumption of the UV curing lamps may exceed the usual dryer consumption, although one plant reports overall energy saving. The UV lamps contain mercury and require special management as a waste.

These inks contain reactive acrylates, monomers and oligomers, some of which are allergenic.

#### Operational data

Printing with UV curing inks in flexography requires 'kiss printing'. UV curing inks have much stronger pigments than other inks. The amount of ink to be transferred must be much smaller. Where in 'normal' flexography the substrate is forcefully locked between the image carrier and the impression cylinder, in UV printing this must be far less. Only very little pressure is used. This is one of the main reasons why retrofit is not possible on most existing flexo presses.

In flexography, in the case of web breakages, the end of the broken web may, on its way to the end of the press, pass a few inkpans and transport ink from one inkpan to the next. This must, of course, be cleaned before printing can restart. In 'normal' flexo, this is cumbersome, but in UV flexo, this is nearly impossible because of the heavy pigmentation and the fact that the ink does not dry. When printing UV flexo, the press design must be such that in case of web breakages, the web is immediately stopped, before the end of the web can drag through any inkpan.

A major problem is presented by the difficulty in cleaning presses where UV curing inks are used. The strong pigmentation and the fact that UV inks do not dry anywhere else than on the substrate means that the smallest amount of contamination makes for serious quality problems. Cleaning is very labour intensive because the inks do not easily dissolve in any solvent. The problem is largest where colours need to be changed between jobs. This is normally the case in printing packaging materials.

In a Dutch plant (see Example plants), cleaning between jobs was prohibitively time-consuming and caused unacceptable quality problems. In order to limit cleaning, a patented system was developed that reduces the number of colour changes drastically. Seven standard colours are used to build up the required colours. This means that seven out of eight printing units do not need to be cleaned between jobs. The eighth printing unit is used to add an additional colour if still necessary. For every job that is switched from 'normal' flexo to UV flexo, all image carriers need to be replaced. (In publications, colour photographs are built up from four standard colours. This system, however, cannot produce every colour and brightness necessary in packaging printing.)

### **Applicability**

UV curing inks can be applied in flexo processes for printing paper packaging materials, labels, and carton packaging materials for dairy products. However, manufacturers of packaging materials for food are often reluctant to employ UV curing inks since the migration of minute quantities of some of the ingredients of these inks into the packed food may lead to non-compliance with food contact legislation. One solution to this problem can be overlacquering of the print in order to protect ingredients (like residual monomers etc) from migrating.

Most paper could be printed with UV inks. The limitation is, however, not the substrate but the existing machinery. Currently, UV curing flexo is used for:

- self-adhesive labels (not likely to be within the IED scope);
- beverage cartons.

In both cases, presses are used that are built specifically for the purpose: labels on small narrow web presses (up to say 25 cm) and beverage cartons on presses with a width of between 100 and 150 cm.

UV curing inks can also be applied to large flexographic printing machines, however, no practical information was submitted.

Not all solvent based inks can be substituted by UV curing alternatives due to the need of specific application properties

### **Economics**

In the case of flexo for beverage cartons, the machines are considerably more expensive than 'normal' flexo presses. Better quality can however be obtained, which is needed in answer to market demands.

Where otherwise increased quality requirements tend to lead to a switch from flexo to gravure, the combination of the run length, customer requirements for regular changes in the printed image and the special substrates used for these cartons, make UV curing flexo an appropriate technique in this case.

### **Driving force for implementation**

~~Implementation of IED. Workplace health and safety. Economic reasons, where there is a need for higher quality with short runs and the high image carrier cost of packaging gravure needs to be avoided.~~

### **Example plants**

Thomas Grafische Veredelung GmbH & Co, KG, Germany. Elopak (Terneuzen, the Netherlands).

### **Reference literature**

[8, Nordic Council of Ministers, 1998] [14, Aminal, et al., 2002, 38, TWG, 2004] [18, UBA Germany, 2003] [78, TWG, 2005] [197, FPE, 2017]

### 12.4.2.2 Electron beam (EB) curable alternatives

#### Description

EB curable inks consist of low molecular weight polymers that react with a stream of electrons from a vacuum tube. These inks contain no solvents and do not cure until exposed to light and may, therefore, remain in ink fountains for long periods of time, reducing clean-up needs. The electrons drive the reaction, forming polymers and setting the ink. See also Section 17.7.2.4

Electron beam dryers use polymerisation by electron bombardment to dry liquid and powdered coatings.

#### Achieved environmental benefits

VOC emissions from ink are reduced to zero.

#### Cross-media effects

No information provided.

#### Operational data

Problems reported with EB curable inks include paper degradation and worker exposure to radiation. They are sometimes used for higher gloss coatings and metal decorating applications.

#### Applicability

Applicable only to new presses.

#### Economics

These dryers have high initial costs and low to moderate operating costs.

#### Driving force for implementation

Implementation of IED. ~~Workplace health and safety.~~

#### Example plants

No information provided.

#### Reference literature

[18, US EPA et al., 2003, 38, TWG, 2004] [197, FPE, 2017]

### 12.4.2.3 Water-based inks

#### Description

Water-based inks contain reduced amounts of organic solvents. Conventional water-based inks rely on relatively highly acid resins for water dispersibility; more recently developed inks are based on water-dispersible polyester resins. (The latter do not need neutralising agents such as ammonia or amines to maintain their dispersibility properties, and therefore meet flexo requirements). See also Section 17.7.2.2.

#### Achieved environmental benefits

In flexo and packaging gravure, press-ready inks contain up to ~~about~~ 80 % solvents. These are always mixtures of several solvents, e.g. ethanol and ethyl acetate. Substitution with water-based inks can result in significant reductions in solvent emissions, particularly of fugitive emissions. However, most flexo and packaging gravure printing plants are equipped with waste gas abatement systems and in that situation the achievable reduction in solvent emission is

clearly smaller. Where waste gases are efficiently treated and excessive fugitive emissions are avoided, little further gain is made by switching to water-based inks. Another major problem is the possible lack of efficiency when running thermic abatements technologies ( non isothermic operation).

Cleaning of water-based inks can be done with water as long as the ink or varnish is not dry.

Water-based inks may require more energy for drying, however, the total plant energy consumption will be reduced because no waste gas treatment system is required (see Section 17.7.2.2. and Annex 14 to the ECM BREF).

### **Cross-media effects**

Water-based inks used in flexo and packaging gravure processes still contain ethanol, isopropanol and/or n-propanol.

The amount of energy needed for drying water-based inks is higher than for solvent-based inks. However, the lack of solvents makes it possible to recirculate the drying air more often and thus reduce the effect. In practice, the increase in energy consumption for drying purposes may be about 10 %.

More waste ink is generated. The quantity of recovered solvent is less and not enough for cleaning purposes

### **Operational data**

In flexography, most paper packaging materials can successfully be printed with water-based inks. Simple plastic packaging materials such as carrier bags, refuse bags, bread bags and heavy duty bags may also be printed successfully with water-based inks in flexography. Applying ceramic anilox cylinders improves the printing quality.

Flexible food packaging materials may be required to be resistant against acids, solvents, fats or oils coming from the food which is to be packed. Currently, these requirements can only be satisfactorily met with solvent-based inks. High quality products meeting these requirements are often printed in packaging gravure, applying solvent-based inks. However, sometimes white ink, the colour which is used most, can be substituted.

Switching from solvent-based inks to water-based inks in flexography or packaging gravure usually requires a different pretreatment of the carrier material and always new printing plates and cylinders.

### **Applicability**

Water-based inks (not varnishes) are successfully applied in flexo packaging printing processes for printing paper sacks, plastic refuse sacks and carrier bags. However, also in these processes conventional inks still need to be applied in some exceptional situations, e.g. for fluorescent effects, gold or silver colours, or where very high gloss is required.

Where water-based products (inks, varnishes, etc.) are applied on existing presses, the dryer systems are often found to lack capacity. This reduces the applicability on existing presses.

Water-based inks are currently not applicable in packaging gravure because a comparable quality cannot be achieved.

### **Economics**

Changing from solvent-based to water-based inks involves substantial changeover costs. For new presses applying water-based inks, the investment is approximately the same as for presses for solvent-based inks. In the case of retrofit, substantial investment may be needed if the dryer capacities need to be enlarged.

Since water-based inks are more highly pigmented, less is needed and the operational cost per m<sup>2</sup> of printed material will generally be somewhat lower than the cost of solvent-based inks.

Where, in the case of water-based inks, printing speed and flexibility can be maintained ~~and the investment in abatement equipment~~ and other solvent related costs can be avoided, substantial savings may result.

#### Driving force for implementation

~~Where operators opt for reduction schemes to comply with IED, this route may be an option (See Economics, above).~~

#### Example plants

Several.

#### Reference literature

[8, Nordic Council of Ministers, 1998] [4, Intergraf and EGF, 1999] [11, IMPEL, 2000] [14, Aminal, et al., 2002] [18, US EPA et al., 2003] [78, TWG, 2005] [197, FPE, 2017]

#### **[Conventional solvent-based varnishes and adhesives]**

*Deleted – not a BAT candidate*

*Conventional techniques have been deleted if they can no longer be considered BAT.*

*This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumptions or emissions.*

~~**Description:** See Section **Error! Reference source not found.** Solvent-based systems are used. The most common solvents are ethanol, ethyl acetate and MEK.~~

~~**Achieved environmental benefits:** No information submitted.~~

~~**Cross-media effects:** High solvents emissions.~~

~~**Operational data:** Exact composition depends on the substrate to be printed. Waste gas treatment is usually applied.~~

~~**Applicability:** No information submitted.~~

~~**Economics:** No information submitted.~~

~~**Driving forces for implementation:** No information submitted.~~

~~**Example plants:** No information submitted.~~

~~**Reference literature:** [18, UBA Germany, 2003] [4, Intergraf and EGF, 1999] [8, Nordic Council of Ministers, 1998] [9, VITO, 1998] [78, TWG, 2005]~~

#### **[Substitutes for conventional varnishes and adhesives]**

#### 12.4.2.4 Water-based varnishes and adhesives

##### Description

Water-based varnishes and adhesives are generally solvent-free (see also Sections 17.7.2.2. & 17.7.2.7)

##### Achieved environmental benefits

Press-ready varnishes and adhesives contain about 80 % solvents. There may be mixtures of several solvents, e.g. ethanol, ethyl acetate and MEK or single solvent systems. Substitution with water-based products can result in significant reductions in solvent emissions, particularly fugitives. However, most flexo and packaging gravure printing plants are equipped with waste gas abatement systems and in that situation the achievable reduction in solvent emission is clearly smaller. Where waste gases are efficiently abated and excessive fugitive emissions are avoided, no further gain is made by switching to water-based inks.

Cleaning of water-based varnishes and adhesives can be done with water as long as they are not dry. However, ethanol, IPA, etc. have to be used if they are dry. ~~are usually used for cleaning.~~

Water-based varnishes and adhesives require a lot of energy for drying, however, the total energy consumption will be reduced **because no waste gas treatment system is required** (see water-based inks, see also Sections 17.7.2.2. & 17.7.2.7). **[TWG please clarify if this is valid]**

The same is valid for the amount of waste water that will on the one hand increase, but in situations where a waste gas adsorption and solvent system is no longer used, the overall amount of waste water will decrease.

### **Cross-media effects**

The energy consumption for increased drying of the water-based products is somewhat higher and more waste is generated. The amount of energy needed for drying water-based inks is higher than for water-based varnishes and adhesives. However, the lack of solvents makes it possible to recirculate the drying air more often and thus reduce the effect. In practice, the increase in energy consumption for drying purposes may be about 10 %.

### **Operational data**

There are a large number of different quality requirements and resistances that apply to a packaging material and therefore the applicability of alternatives for traditional solvent-based inks, varnishes and adhesives is never obvious. For example, the varnish may be required to have a certain resistance against slip in order to accommodate the specifics of the packaging machines, which can only be achieved by applying solvent-based varnishes. They also show a lower chemical resistance compared to solvent-based adhesives besides the lower adhesive starting and composite strength; for these reasons, water-based cannot be used for all types of applications.

In the special lamination process where a thin paper is attached to plastic or aluminium, water-based products are suitable because the water can evaporate through the paper. For the lamination of two non-porous films, water-based products are less suitable because they require a longer drying time before the films can be put together. In these situations, solvent-based or two-component solvent-free adhesives are used.

### **Applicability**

Applicable in all printing and laminating processes in the manufacturing of flexible packaging. It is commonly applied in flexo and packaging gravure plants. However, they cannot replace the solvent-based varnishes in all situations.

Where on existing presses water-based products (inks, varnishes, etc.) are applied, the dryer systems are often found to lack capacity. This reduces the applicability on existing presses.

### **Economics**

No general valid statement on costs can be made.

### **Driving force for implementation**

Occupational health and safety. ~~HED.~~

### **Example plants**

No information provided.

#### **Reference literature**

[8, Nordic Council of Ministers, 1998] [14, Aminimal, et al., 2002] [14, DFIU and IFARE, 2002] [78, TWG, 2005] [197, FPE, 2017]

#### **12.4.2.5 High-solid varnishes and adhesives alternatives**

##### **Description**

Use of high-solid varnishes and adhesives that contain up to 40% solids, resulting in reduction of solvent consumption and emission.

Traditional solvent-based adhesives contain up to 80 % solvents, where high-solid adhesives contain up to ~~some~~ 60 % solvent. Where the original adhesives need 4 kg solvent for each kg of solids, the alternative only up to ~~needs~~ 1.5 kg. In this case, a reduction of solvent consumption of more than 60 % is attained.

##### **Achieved environmental benefits**

Reduction of solvent emissions.

##### **Cross-media effects**

Waste gas treatment techniques may still be necessary.

##### **Operational data**

High-solid adhesives are applied in lamination processes for flexible packaging. They are applied in the high performance sector for mechanically, thermally or chemically stressed packages and in the production of composites changing in material within one lamination installation.

##### **Applicability**

Applicable in new and existing plants.

##### **Economics**

No information provided.

##### **Driving force for implementation**

No information provided.

##### **Example plants**

~~No information provided.~~ Site by site situation

##### **Reference literature**

[14, DFIU and IFARE, 2002, 38, TWG, 2004] [197, FPE, 2017]

#### **12.4.2.6 UV curing varnishes and adhesives alternatives**

##### **Description**

UV curing varnishes and adhesives used for lamination do not contain organic solvents.

##### **Achieved environmental benefits**

Where varnishes or adhesives based on volatile solvents are used, a significant reduction in solvent emissions can be achieved.

##### **Cross-media effects**

UV curing varnishes and adhesives require energy to be dried by specific UV dryers. However, this is unlikely to be more than for drying conventional solvent-based systems. In addition, the lamps used contain mercury and require special treatment as waste.

UV curing varnishes and adhesives contain reactive acrylates, monomers and oligomers, some of which are allergenic.

### **Operational data**

In the flexible packaging industry next to printing, laminates containing a number of different plastic films and aluminium foil are often made. UV curing adhesives are applied here, however, only for standard composites up to a medium quality level.

### **Applicability**

Applicable in new and existing plants and installations.

### **Economics**

No general valid statement on costs can be made.

### **Driving force for implementation**

No information provided. Site by site situation

### **Example plants**

No information provided.

### **Reference literature**

[8, Nordic Council of Ministers, 1998] [14, Aminimal, et al., 2002] [14, DFIU and IFARE, 2002, 38, TWG, 2004] [78, TWG, 2005] [197, FPE, 2017]

## **12.4.2.7 Solvent-free varnishes and adhesives alternatives**

### **Description**

Solvent-free adhesives are two-component adhesives with a 100 % solid content, often containing isocyanates.

### **Achieved environmental benefits**

Solvent emissions from adhesive applications are reduced to zero.

### **Cross-media effects**

No information provided. Risk of isocyanate emissions in work places.

### **Operational data**

These are commonly applied in the flexo and packaging gravure industry in the lamination processes on non-porous substrates such as plastic and aluminium.

A general problem of these solvent free systems is the application of thin, uniform adhesive films. As opposed to the solvent-based adhesives where layer thickness can be controlled by the viscosity, the control has to be carried out by mechanical rolling processes. The adhesive layer might show slightly increased surface irregularities compared to solvent-based adhesives.

Many complex laminates can be produced with two-component systems. They require special machinery.

### **Applicability**

No information provided.



**Economics**

No information provided. Depends on customers needs

**Driving force for implementation**

~~IED~~. Occupational health and safety. Client's product specifications.

**Example plants**

No information provided.

**Reference literature**

[8, Nordic Council of Ministers, 1998] [14, Aminimal, et al., 2002] [14, DFIU and IFARE, 2002] [197, FPE, 2017]

**12.4.2.8 Co-extrusion****Description**

~~With co-extrusion~~, The printed substrate is covered with a warm, liquefied plastic film and subsequently cooled down. This film replaces the ~~necessary~~ varnish layer, or when used between two different layers of different carriers, it acts as an adhesive.

**Achieved environmental benefits**

Solvent emissions are eliminated.

**Cross-media effects**

Co-extrusion requires energy.

**Operational data**

Applied in flexible packaging.

**Applicability**

~~No information provided~~. Case-specific

**Economics**

No information provided.

**Driving force for implementation**

~~IED~~. Occupational health and safety. Client's product specifications.

**Example plants**

No information provided.

**Reference literature**

[14, Aminimal, et al., 2002] [78, TWG, 2005] [197, FPE, 2017]

**12.4.3 Waste gas extraction and treatment****12.4.3.1 Encapsulation/enclosure****Description**

See Sections 17.10.2.1 & 17.10.2.6.

Evaporation can be reduced by: covering ink fountains; using chamber doctor blades; encapsulating varnishing or lamination units.

**Technical description**

In flexible packaging, the dryers are always enclosed. They work at sub-atmospheric pressure to avoid sending solvent laden air into the press room. They thus always extract a part (often some 20 %) of their inlet air from the press room. The waste gases are emitted through a stack or sent to abatement equipment.

Solvents not only evaporate in the dryer, they also evaporate from ink fountains, viscosity adjusters, containers, etc. These solvents should ~~must~~ be extracted locally for health and safety reason, in order not to exceed occupational exposure limits (OEL).

Local extraction is normally ~~not~~ sent to abatement equipment ~~due to the low solvent concentration.~~

### **Achieved environmental benefits**

See Section 17.10.2.1. Enclosure or encapsulation reduces the volumes of air to be extracted, and therefore reduces the size of extraction fan motors and waste gas treatment where applied.

Reducing solvent emissions. Solvent emissions from washing machines may be several per cent of the total solvent consumption.

### **Cross-media effects**

~~Safety needs to be assured. At the times that the solvent concentration in the ventilation air from the washing machine is at its highest, adequate dilution with waste gases from production machinery or otherwise is necessary to prevent explosions.~~

### **Operational data**

Automatic cleaning machines need to be ventilated before unloading. During a few minutes, a relatively small airflow (a few thousand m<sup>3</sup>/h) is heavily laden with solvent vapours. This airflow is sent to the abatement equipment.

### **Applicability**

Generally applicable to automated machines. Enclosure of ink fountains, viscosity adjusters, containers, etc., are increasingly used ~~to meet IED requirements.~~ Retrofit is ~~not~~ possible (machine control needs to be completely automated). Dryers are always enclosed

### **Economics**

No information provided.

### **Driving force for implementation**

~~Implementation of the IED.~~ Occupational health and safety.

### **Example plants**

~~No information provided.~~

Almost all of plants that submitted information

### **Reference literature**

[38, TWG, 2004] [78, TWG, 2005] [155, TWG, 2016] [197, FPE, 2017]

## **12.4.3.2 Extraction and treatment of air from the presses and other production areas**

### **Description**

Solvents evaporating from the presses, such as from containers for ink, varnishes and adhesives, from venting automatic cleaning machines (see Section 17.10.2) and escaping capture by the dryers, are extracted locally and subsequently treated.

The following can be applied:

- Encapsulating the laminating and varnishing machines and ventilating the enclosure by the dryer extraction rather than local extraction.
- Sending local extraction around production machinery to abatement.
- ~~Ensuring~~ Relevant fugitive emissions from ink fountains are captured and treated. This reduces the need for local extraction of open areas.
- Installation and use of chamber doctor blades (~~see Section Error! Reference source not found.~~).
- Sending washing machine ventilation to abatement (see Section 17.9.7).

#### Achieved environmental benefits

Reduction of VOC emissions. Assures the capture and treatment of fugitive emissions from ink fountains and washing machines.

~~Automatic washing machines need to be ventilated before they can be unloaded (see Section Error! Reference source not found.). This ventilation is often not sent to the abatement equipment.~~

#### Cross-media effects

Extraction requires energy, but this local extraction takes place to prevent high occupational exposure levels. The issue is whether or not to send the extracted air to the waste gas treatment (usually an incinerator). However, since the abatement incinerator may need to be larger, the main fan of this incinerator would also be much larger. This would substantially increase the amount of energy required. The increased airflow with a low solvent content will increase the amount of support fuel required by an incinerator.

#### Operational data

Modern packaging gravure presses are, apart from extraction of the dryers, equipped with floor extraction and/or extraction from the ink containers to the waste gas treatment system. This extracted air may contain about 1 g solvent/m<sup>3</sup>, but this which will depend on other measures taken to reduce fugitive emissions, and may be lower. These additional extraction systems are placed between the printing units. For flexo presses equipped with a central impression cylinder, the available space between the printing units is too small to install an extraction system, see Figure 12.1.

Modern standalone varnishing and lamination units are usually equipped for this.

#### Applicability

Not applicable on existing flexo presses equipped with a central impression cylinder. In-built in new standalone varnishing and lamination units.

~~The venting of automatic washing machines is commonly applied where incineration has recently been installed. Generally not applicable where solvents are recovered for reuse, since recovered solvents are used for cleaning that cannot be reused in inks, varnishes or adhesives.~~

#### Economics

Depends mainly on the capacity of the waste gas treatment system. ~~In packaging gravure, costs for retrofit are over EUR 100 000.~~

Where locally extracted air is always sent to the incinerator, the incinerator would need to have some 20 % additional capacity. ~~A newly built incinerator would therefore be about EUR 150 000 to EUR 300 000 more expensive, assuming the original capacity would be between 75 000 m<sup>3</sup>/h and 150 000 m<sup>3</sup>/h. Retrofitting an incinerator to enlarge its capacity by 20 % is often technically not possible or far more expensive (2004).~~

#### Driving force for implementation

Implementation of IED.

**Example plants**

No information provided.

Widely applied

**Reference literature**

[8, Nordic Council of Ministers, 1998] [14, Aminimal, et al., 2002] [4, Intergraf and EGF, 1999, 38, TWG, 2004] [78, TWG, 2005] [197, FPE, 2017]

**Peak volume bypass and peak/trough smoothing: extraction and treatment of air from the presses and production areas**

*Proposed for deletion as the environmental benefit is not demonstrated.*

**12.4.3.3 Inspection and maintenance to reduce solvent emissions during OTNOC [Maintenance of waste gas treatment equipment, bypasses, collection systems, etc.]**

**Description**

Ensure planned maintenance and speedy repairs are carried out, see Section 17.2.7.

**Achieved environmental benefits**

Defects in incineration equipment can give rise to VOC emissions of up to 0.4 % of the annual input per day (assuming 250 working days a year).

**Cross-media effects**

No information provided.

**Operational data**

In seven IED-size Dutch flexible packaging plants, the downtime of incinerators varied between 1 and 14 working days. The average was almost 7.5 days, i.e. about 3–8 % of total annual input. These data are from 2004.

**Applicability**

All plants.

**Economics**

No information provided.

**Driving force for implementation**

IED.

**Example plants**

No information provided.

**Reference literature**

[38, TWG, 2004]

**12.4.3.4 Automatic and timely closure of a bypass system**

*TWG please provide updated information*

**Description**

Waste gases from the dryers should be sent to the incinerator automatically before make-ready press speed is reached (30–60 m/min).

**Achieved environmental benefits**

A 5–15 % reduction in emissions can be achieved.

**Cross-media effects**

No information provided.

**Operational data**

No information provided.

**Applicability**

~~No information provided.~~ Generally applicable.

**Economics**

No information provided.

**Driving force for implementation**

No information provided.

**Example plants**

No information provided.

**Reference literature**

[38, TWG, 2004] [78, TWG, 2005]

**12.4.3.5 Removal of residual solvent in non-food printed materials**

See Sections 13.4.2.1 and 13.4.2.2.

TWG: Mentioned in

**Description**

Residual solvent in the product can be minimised by increasing the drying time and/or increasing the temperature in the press room, and extracting to WGT.

**Technical description****Achieved environmental benefits****Environmental performance and operational information****Cross-media effects****Technical considerations relevant to applicability**

Generally applicable.

**Economics****Driving forces for implementation****Example plants****Reference literature**

No information provided

**12.4.3.6 Cryogenic solvent recovery**

See Section 17.10.6.2

#### **12.4.4 Cleaning techniques**

##### **12.4.4.1 Replacement of VOCs with less volatile solvents for cleaning floors (substitution)**

###### **Description**

See Section 17.9.

###### **Achieved environmental benefits**

A reduction in the emission of VOCs of 1–2 % can be achieved from a situation where floors are cleaned by wetting with buckets of solvents. However, where some preventative measures are already taken, such as reducing the dirtying of the floors and controlling solvent use, the reduction in emissions is less.

###### **Cross-media effects**

No information provided.

###### **Operational data**

No information provided.

###### **Applicability**

No information provided.

###### **Economics**

No information provided.

###### **Driving force for implementation**

No information provided.

###### **Example plants**

No information provided.

###### **Reference literature**

[78, TWG, 2005].

##### **12.4.4.2 Cleaning machine parts and equipment in automatic cleaning/washing machines**

See Section 17.9.7.

##### **12.4.4.3 Cleaning of machine parts with high-pressure water spray**

See Section 17.9.9.

##### **12.4.4.4 Dry ice cleaning**

See Section 17.9.11.

## 13 PUBLICATION GRAVURE

### 13.1 General information

[149, ERA 2016] [196, ERA, 2015]

The European publication rotogravure industry uses 180 000 tonnes of ink annually (2006). This consists of 30 kt pigments, 50 kt resins and 100 kt toluene. More than 95 % of the toluene is reused: this is possible because gravure uses a mono-solvent system. The formation of azeotropes (constant-boiling mixtures, which hinder purification) is not possible, so it is not necessary to distil the recovered solvent. This saves time, costs and energy. The recovered pure toluene can be reused on site or delivered back to the ink maker.

The productivity of gravure printing is very high. Advanced presses can print on a 4.32 m wide paper web at speeds of up to 16 m/s. Even with smaller units, the energy used per square metre of printed product is less than in alternative printing methods. However, this advantage increases the longer the print run.

The main environmental advantages of publication gravure printing are:

- the use of easily recyclable raw materials;
- the usage of renewable raw materials;
- the production of a very easily recyclable product.

There are currently 32 printing plants in Europe, operating 125 gravure presses. Publication gravure is applied to print magazines, catalogues and supplements with high print runs:

- news magazines, TV magazines, women's magazines, etc.;
- publications;
- catalogues;
- supplements, inserts and flyers published by large department stores and supermarket chains, etc.

The turnover of the publication gravure printers currently amounts to around EUR 3.5 billion per year.

## 13.2 Applied processes and techniques

### Gravure

[4, Intergraf and EGF, 1999] [8, Nordic Council of Ministers, 1998] [11, IMPEL, 2000] [78, TWG, 2005]

In gravure printing, the image consists of small indentations in a smooth surface of a cylinder. This consists of a steel base which is plated with copper and covered with a thin layer of hard chromium. It tends to be a more specialised process than either relief or litho printing, being mainly used for long runs as the cylinder making costs are relatively high. In this process, the cylinder is flooded with ink, and the surface scraped clean to leave ink only in the recessed, image areas.

The image carrier in the gravure process is generally a steel cylinder with a copper-plated surface in which small recesses, called 'cells', are made which carry the ink. The surface is normally then plated with hard chromium to improve its wearing properties.

In the press, there is a printing unit for each cylinder. The surface of the rotating cylinder dips into an ink pan which fills the cells with ink (the inks for gravure printing are very fluid, whereas offset litho ink is paste-like). Surplus ink is then wiped off the cylinder surface by the squeegee action of the doctor blade, leaving only ink in the cells. The impression roller then presses the paper web onto the cylinder, and the ink transfers onto the paper.

Gravure applies the ink in controlled doses from different sizes of cell. The larger the volume of the printing cells, the more ink is transferred and the stronger the tone which is reproduced by them.

Gravure is used for printing two major graphic products: publications and flexible packaging which is discussed in Chapter 0 of this document. Minor graphic applications are labels, gift wrapping paper, cardboard packaging, banknotes and postage stamps. Outside the graphic industry, this method is used for the printing of wallpaper, imitation wood (laminates) and imitation tiles for floors and walls.

**Table 13.1: Technical characteristics of publication gravure presses**

	<b>Publication gravure</b>
<b>Web width</b>	900–4 320 mm
<b>Printing units</b>	Mostly 8 units, sometimes 9 or 10 units
<b>Production speed</b>	15 m/sec = 900 m/min
<b>Construction</b>	Mostly 4 units per side of paper
<b>Colours</b>	Four inks in 8 units, five inks in the case of 9 or 10 units possible
<b>Substrates</b>	Paper
<b>Solvents in use</b>	Toluene > 99.9 % pure
<b>Abatement techniques</b>	Solvent recovery plant

Publication gravure is best known for being capable of producing very high-quality colour printing on lower quality, cheaper grades of paper. The press web width can be anything



between 900 mm up to 4 320 mm at speeds of up to 16 m/s. Most publication gravure presses have eight printing units, one for each of the four process colours (YMCK) for each side of the paper. Occasionally a fifth printing unit per side is included (i.e. 10 units altogether) to allow a 'spot colour' such as a metallic or fluorescent ink for special effects [149, ERA, 2016]. ~~usually with eight units printing four colours on each side [15, CITEPA, 2003]. The paper that runs through the press can reach a speed of up to 15 metres per second.~~ Today's rotogravure presses for publication gravure run at 15 m/s and more.

Today, gravure is almost totally a webfed process, although sheetfed presses are available running at up to 10 000 sheets per hour. These have hot air dryers and are aimed at the specialised markets of high quality decorative effects using metallic inks on metallised papers and foils. They are, however, seldom used at present, presumably because of the high costs of cylinder making, which make high (web) run lengths more economic [4, Intergraf and EGF, 1999].

Other similar processes are copperplate printing and die-stamping. Both employ the filling of recessed image areas with ink, but in these cases, the ink is thick and dries by oxidation and adsorption rather than relying on solvent evaporation. Copperplate is used for the printing of banknotes and other security documents, while die-stamping is employed for letter headings.

### **Cylinder preparation**

[149, ERA, 2016]

In the past, gravure cylinders were produced with photographic films and etching. This was a complex process which needed time, raw materials and energy and led to some chemical waste. Nowadays, these production steps have been completely replaced by digital data handling. The final step of producing the cells in the surface of publication gravure printing cylinders is done either electromechanically or with a laser installation, so etching is no longer necessary. The surface is then plated with a hard chromium layer to improve its wearing properties. Nowadays, most gravure printers buy the necessary chromium compound in dissolved form, which means that dust occurrence is no longer possible. As a sideline, the surface has a higher quality because the continuous flow of the solution holds the concentration of the chromium ions during the galvanisation constant.

### **Inking unit**

[8, Nordic Council of Ministers, 1998] [15, CITEPA, 2003]

The high speed of gravure presses requires the use of fast drying inks, which are dried between colours in dryers. Therefore, in gravure, inks are low in viscosity and nearly all of them are solvent-based. Publication printing inks contain 50 % toluene when leaving the ink factory. A dilution is made in the printing plant to obtain the proper toluene concentration: ink that is ready for use contains 70–80 % toluene. The solvents are evaporated by heat and air in drying sections, see Figure 13.1 which shows that each printing unit is equipped with a dryer on top [38, TWG, 2004].

One installation reported the application of ElectroStatic Assistance (ESA) for ink transfer in printing units. An electric field is generated in the region of the nip between the impression roller and the gravure cylinder (where ink transfer takes place). This technique has as main benefits: improvements in print quality, especially on less expensive stock, less waste, reduced need for high impression pressures, faster press speeds, decreased impression roller heat build-up, and a resultant increase in roller life [155, TWG, 2016, #030].

All installations in the publication gravure in Europe are equipped with activated carbon adsorbers to recover the toluene that is evaporated [15, CITEPA, 2003]. The presses are normally encapsulated. The recovered toluene is reused either on site to dilute the ink, or sold to the ink supplier.

Water based gravure inks have not yet proved very successful and, until now, only used sporadically in packaging printing. The use of water based gravure inks in the United States has now ceased [8, Nordic Council of Ministers, 1998] [38, TWG, 2004].

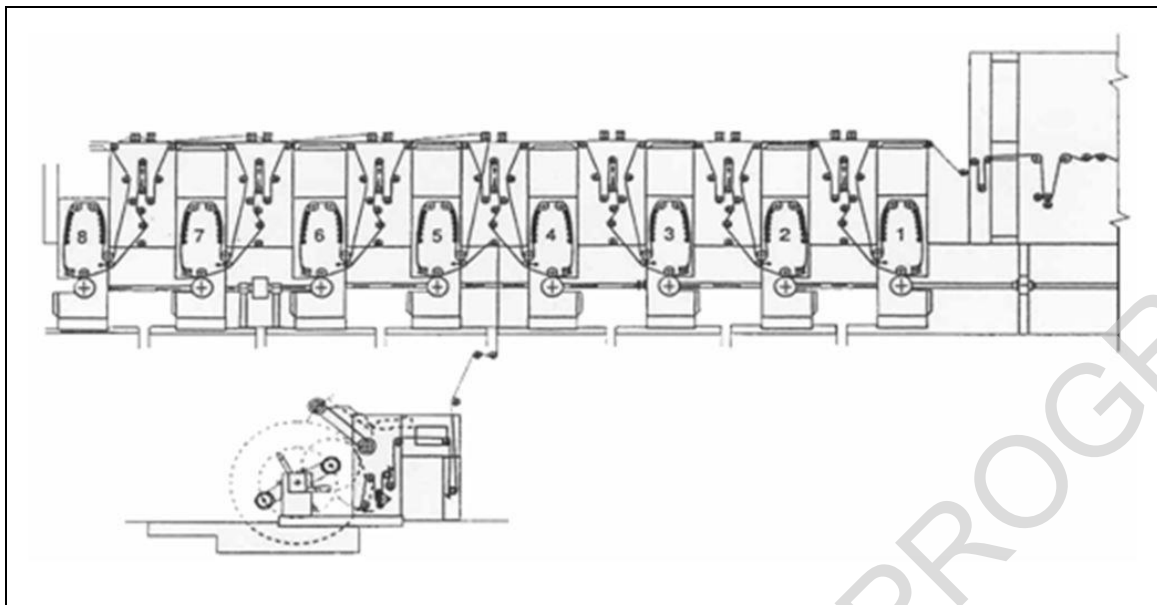


Figure 13.1: 4 + 4 colour publication gravure press

### Printing ink

[149, ERA, 2016].

Some toluene is lost as traces in the printed products. This amount has been significantly lowered in recent years. This was mainly achieved through modification of the ink composition. The surface of the printed ink takes slightly more time to solidify. In this short time period, around 10 milliseconds, additional toluene evaporates in the printing unit and is caught by the recovery system. When the printed matter leaves the production site, the toluene traces are in any case lower than 0.04 %. In consequence the airborne toluene concentration in nearby sensitive areas is far below  $260 \mu\text{g}/\text{m}^3$  of air. The figure of  $260 \mu\text{g}/\text{m}^3$  is the maximum limit accepted by the WHO for private homes. At the workplace, and already including a high safety margin, the maximum concentration allowed is  $190 \text{mg}/\text{m}^3$  as average over an eight-hour working day.

The pigments in the gravure printing inks are synthetic, mostly based on petrochemicals. Ink providers (European Printing Ink Makers Association) have established an 'Exclusion List for Printing Ink and Related Products' which excludes toxic and other very harmful materials as ingredients. The resins of the gravure inks based approximately 80 % on natural materials, for example rosin, gum rosin, tall oil resin. The last is a by-product of chemical pulp production in the paper industry.

### Paper

Years ago it seemed impossible that high-quality publication gravure products could be printed on paper which contains recycled fibres. Recent developments in the paper production industry have changed this situation and allow the production of high-quality products and for the customers' demands to be met.

At the same time, it was possible to reduce the paper basis weight (grammage) without losing the optical properties. The recycling rate for printed matter in Europe is 55 % (2005): if the European recovered paper which is recycled outside Europe is included, the rate reaches 63 % (2005).

**Cleaning**

Cylinders are automatically or manually cleaned with the same solvent as the ink. If the job is expected to be repeated, the cylinders might be saved, or else they are made ready for the next printing job by replacing the engraved copper/chromium layer with a new one [38, TWG, 2004].

**Finishing**

[4, Intergraf and EGF, 1999] [8, Nordic Council of Ministers, 1998]

Print finishing services are provided by printing companies themselves and also by a number of specialised, independent plants (purely print finishing plants).

The most important print finishing services include the processing of:

- books by folding, collecting, stitching, binding and trimming;
- magazines, leaflets, catalogues and printed advertising products (e.g. brochures, sample cards, etc.) by folding, gathering, gluing and perfect binding;
- other printed matter, printed papers or cardboard (e.g. forms, labels, packaging, calendars) by folding, punching, embossing, gluing and laminating.

Each of these steps will involve guillotining and collating. These mechanical processes, as well as folding, binding and punching, do not use solvents and, therefore, are not described any further in this document. In processes such as gluing and laminating, however, solvent-based products are sometimes used, and so these are further described.

**Laminating**

Traditionally, most laminating was done with solvent-based systems, where the adhesive-coated film was passed through an oven to drive off the solvent before being pressed onto the printed surface. Nowadays, two-component adhesives are used, often of the epoxy type containing solvents such as ethanol and ethyl acetate, or of the urethane type. The emissions from this process are significant. In some places, the vapours are incinerated or recovered for reuse. Water-based and solvent-free adhesives or UV curing laminating adhesives are also applied [38, TWG, 2004].

**Binding by using adhesives (gluing)**

Gluing is part of many working processes in bookbinding and print finishing. For the processing of the book block and the production of, e.g. the case for hard case books, adhesive binding is the most frequently used binding technique, both for books and multiple page leaflets. Adhesive binding is often referred to as 'perfect binding'.

The adhesive used can be based on natural products or can be synthetic. The latter one may be dispersion, hot melt or polyurethane. Natural products mainly comprise starch adhesives, dextrans and animal glues.

Traditionally, most used glues are water-based or hot melt and some are solvent-based.

**Varnishing**

'Coating', 'varnishing' and 'overprinting' are synonyms for the coating that is spread over the printed surface for protection or decoration. The overprint varnish is a colourless, transparent ink without pigments. Varnishes dry by evaporation, oxidation or by UV curing, and varnishes can be applied in line on the press or on a separate machine [8, Nordic Council of Ministers, 1998] [38, TWG, 2004].

### 13.3 Current consumption and emission levels

#### 13.3.1 Mass balances

[18, UBA Germany, 2003] [78, TWG, 2005] [155, TWG 2016]

*TWG: please confirm if this data is valid and please provide new information.*

In 1999, the results of an inventory amongst publication gravure plants in Germany were reported. One of the results of this inventory was that the performance data from different units of different plants were compared and used to simulate a virtual plant that could meet the legal requirements, especially those of the Solvent Emissions Directive [38, TWG, 2004]. In this section, a mass balance for a good practice plant (selected from the inventory) is reported, followed by data for the virtual plant.

#### A good practice plant

In this section, data of a good practice plant from this inventory are reported along with the mass balances of the virtual plant. The virtual plant is, as explained above, not an existing plant, but made up of well-performing units from different existing plants. The good practice plant is a modern publication plant with five presses containing forty ink units in total. The products are mainly magazines and catalogues which both need to be of high quality. The operational data of this good practice plant are as shown in Table 13.2:

**Table 13.2: Mass balance of a good practice publication gravure plant**

INPUT	Amount	Unit	Notes	OUTPUT	Amount	Unit	Notes
Material				Products			
Pre-products	3 100	t/yr		Pre-products	86 367	t/yr	Paper and ink
				Waste			
Printing substrate	91 300	t/yr		Substrate/misprints	8 005	t/yr	
Printing inks	2 210	t/yr	Including varnish	Ink/varnish residues	15.7	t/yr	Hazardous
Water: of which	158 150	m <sup>3</sup> /yr	Well water	Sludge	7.5	t/yr	Hazardous
	123 100	m <sup>3</sup> /yr	Cooling				
	9 000	m <sup>3</sup> /yr	Cylinder preparation	Activated carbon	2.6	t/yr	From adsorbers
	6 500	m <sup>3</sup> /yr	Heating	Waste water			
Wipes	600 125	Items/yr that are cleaned	Reusable wipes	To sewage	33 200	m <sup>3</sup> /yr	2 418 m <sup>3</sup> /yr from electro-varnishing
Energy				Waste gas			
Energy in total	67 509	MWh/yr		VOC in purified gas	7.2	t/yr	Average * 35 mg C/m <sup>3</sup>
Gas energy	44 051	MWh/yr		NO <sub>x</sub> from combustion plant	7.6	t/yr	Natural gas combustion
Electric energy	24 011	MWh/yr		CO from combustion plant	0.2	t/yr	Natural gas combustion
				Fugitive			
				VOC fugitive	365	t/yr	

\* The waste gas average of 35 mg C/m<sup>3</sup> is low and will be associated with a high energy demand.  
 Source: [38, TWG, 2004]. [18, UBA Germany, 2003] [38, TWG, 2004]

#### The virtual plant

The VOC balance of the virtual plant by employing emission factors that are typical for the branch, gives the following results shown in Figure 13.2 below. Inks, when bought, contain on

average 50–55 % of toluene rather than 45 % (gravure varnish contains 45–55 % VOCs). However, it does not affect the calculations, as after dilution, the figures approximately balance. VOC in ‘clean gas’ equals a recovery efficiency of 99.9 %, which is exceptional and far lower than usual good practice, is technically very difficult to achieve and would create a large energy demand. The average airflow is 19 000 Nm<sup>3</sup>/h, which is unusual in practice and 100 000 m<sup>3</sup>/h would be much more likely [38, TWG, 2004].

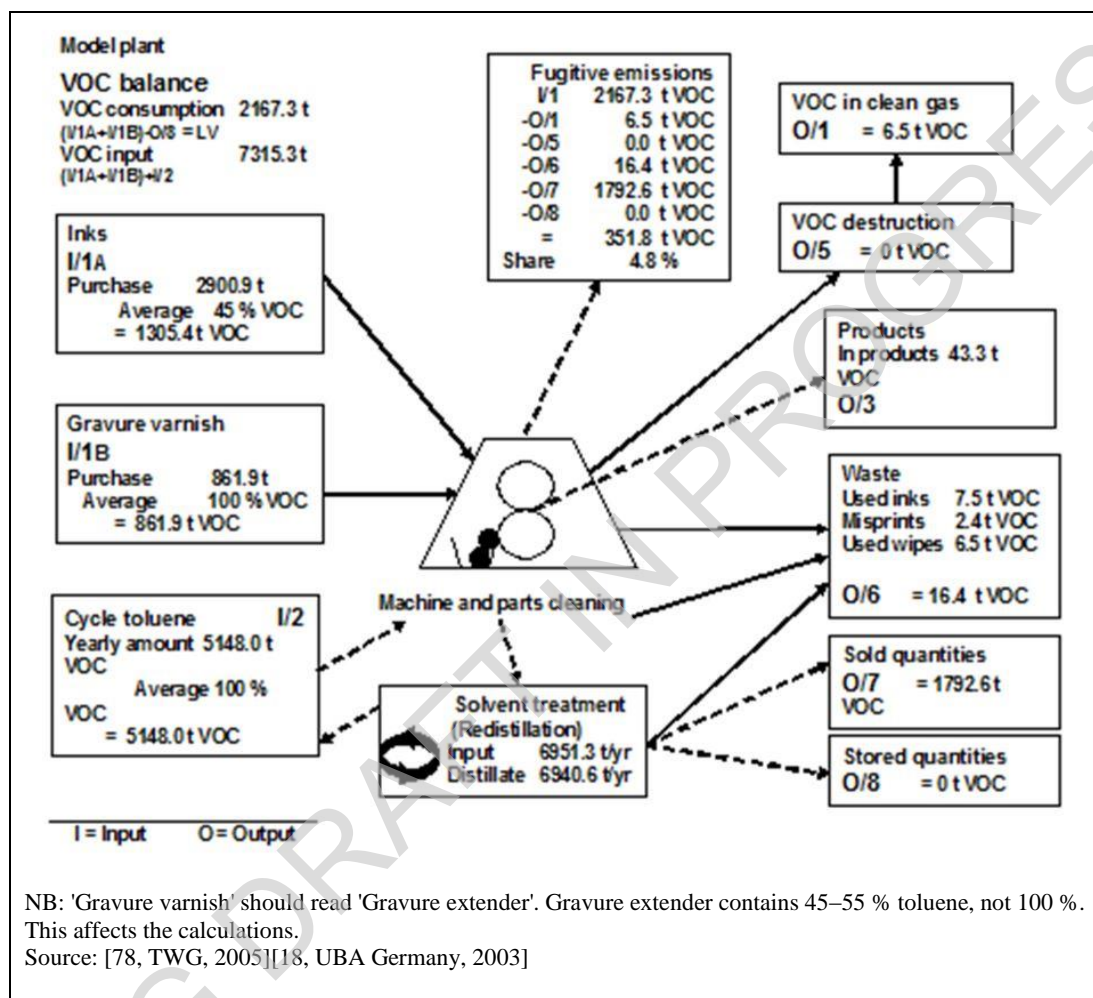


Figure 13.2: VOC balance of a virtual publication gravure plant

This mass balance is, in theory, achieved by applying the following reduction measures:

- the applied printing inks are retention inks (see explanation below);
- air extraction is applied at collecting places of ink residues and solvent wipes;
- periodic cleaning of persistent contaminants is done with dry ice instead of solvents;
- the performance of the toluene adsorber is continuously monitored;
- the drying air from the toluene adsorber is led through the waste gas scrubber.

In ‘retention inks’, formation of a skin on the ink surface is delayed by a modified recipe. In this way, a higher percentage of the toluene contained in printing ink can be expelled directly into the ink drying unit of the printing plant [18, UBA Germany, 2003].

Some key VOCs in illustration gravure are shown in Table 13.3. From this table it can be calculated that for each tonne of purchased ink, 1.86 tonnes toluene (partly recovered and partly fresh) is used. Data from two plants show a specific toluene input of 1.96 and 1.48 tonnes respectively for each tonne of purchased ink; see Table 13.4. However, it is not clear if this

refers to the ratio of toluene to solids; this is the only accurate basis to compare with ink input [38, TWG, 2004].

**Table 13.3: VOCs in publication gravure**

Substance	Vapour pressure at 20 °C (kPa)	Specific input (wt-% of purchased ink input)	Use
Toluene	2.9	54.7	Solvent in ink and gravure varnish
		100	Thinner in the printing process
		2.5–7.5 [78, TWG, 2005]	Cleaning agent [38, TWG, 2004]
Ethanol	5.9	< 1	Siccative for cylinder correction
Turpentine substitute	0.04	< 1	Cleaning agent for cylinder correction
Acetone	24.0	< 1	Cleaning agent for cylinder correction

Source: [18, UBA Germany, 2003]

**Table 13.4: Specific toluene input of two plants in Flanders, Belgium**

	Purchased ink input (t/yr)	Total toluene input (fresh and recovered) (t/yr)	Specific toluene input (wt-% of purchased ink input)
Plant 1	1 312	2 571	196
Plant 2	1 475	2 179	148

Source: [13, Aminal, et al., 2002]

Toluene balances of the two gravure printing plants with a total of five presses situated in Flanders (Belgium) are shown in Table 13.5. The fugitive toluene emissions are 10 % and 6 % respectively. The technique for achieving zero toluene in the waste of Plant 2 has not been identified [38, TWG, 2004].

**Table 13.5: Toluene balances of two gravure printing plants**

	Plant 1	Plant 2	Unit
Total toluene consumption (fresh and recovered)	2 571	2 179	t/yr
Toluene in waste	11	0	t/yr
Toluene in sold product	10	10	t/yr
Toluene recovered and reused on site	1 694	1 428	t/yr
Toluene recovered and sold	599	613	t/yr
<b>Emissions</b>			
Toluene emissions after treatment	1.1	4	t/yr
Fugitive toluene emissions <sup>(1)</sup>	265	133	t/yr
Total toluene emission	266.1 (10 %)	137 (6 %)	t/yr (% of consumption)

<sup>(1)</sup> Inclusive of 10 tonnes toluene in the sold product.  
Source: [13, Aminal, et al., 2002]

Data from only four publication gravure installations were submitted in the frame of the data collection [155, TWG 2016]

### 13.3.2 Consumption

[155, TWG 2016]

#### 13.3.2.1 Printing inks

The European publication rotogravure industry uses 180 000 tonnes of ink annually (2006). This consists of 30 kt pigments, 50 kt resins and 100 kt toluene.

All inks used in publication gravure are toluene-based. Table 13.6 shows an average basic recipe for publication gravure. In the printing plant, inks of this type of recipes are significantly thinned before being used. The toluene concentration of the press-ready ink is in the range of 70–80 wt-%.

**Table 13.6: Average basic recipe of purchased publication gravure ink**

Component	Contents	Concentration (wt-%)
Binding agent:		
- Solvent component	Toluene	50–60
- Binding agent component	e.g. phenol resins, hydrocarbon resins, ethyl cellulose	30–40
Colourants	Organic and inorganic pigments	8–20
Colour auxiliary agents	e.g. waxes, dispersants, defoamers	1–4
<i>Source: [18, UBA Germany, 2003]</i>		

Reported data on solvent content of publication gravure inks show a variation from 54 % to 61 % [155, TWG 2016].

The amount of ink used in the publication printing plants participating in the data collection, varies from 1 up to 2.8 million kg. The solvent content in purchased ink materials as well as the reused solvent quantities are presented in Table 13.7

**Table 13.7: Ink consumption and solvent input data from publication gravure installations**

Installation	Solvent content in purchased inks (as %)	Solvent quantity recovered and reused as solvent input (as % of the purchased inks)
1	54.3	215
2	51.9	217
3	58.7	166
<i>Source: [155, TWG, 2016]</i>		

The reported figures for solvent consumption of substrate varies from 70 kg/t up to 92 kg/t, while the average solvent consumption per millions of m<sup>2</sup> of substrate varies from 2.1 kg up to 4.8 kg/10<sup>6</sup>m<sup>2</sup>.

The amount of ink used in the publication printing industry is vast; an average four press plant may use 10000 tonnes of press ready ink per year and will consequently have a solvent input of about 8000 tonnes. Of this amount, some 7000 tonnes are recovered and either re-used or sold back to the ink manufacturer [4, Intergraf and EGF, 1999].

Water-based inks have been the subject of experiment. A major problem is that, with the existing paper recycling processes, de-inking of the paper is not possible. This, in combination with lower press speeds, print problems with wide web widths and cross-media effects, has led to cessation of their use [4, Intergraf and EGF, 1999] [38, TWG, 2004].

A successful development of publication gravure inks has led to a new generation of toluene-based inks known as 'retention inks'. Their formulation has been modified in such a way that the toluene evaporates more efficiently in the dryers. Although they contain about 5 % more toluene when press-ready, they can lead to less fugitive emissions. These new inks are distributed by several manufacturers [15, CITEPA, 2003] [18, UBA Germany, 2003] [14, Aminal, et al., 2002].

### 13.3.2.2 Cleaning agents

All inks used in publication gravure are toluene-based. Once dry, they re-dissolve in toluene, which is, therefore, used as the cleaning agent. Data on the amount of cleaning agents used are not available, however, only the relative value in Table 13.3 shows that for each tonne of purchased ink, 2.5–7.5 wt-% toluene is used for cleaning [78, TWG, 2005]

VOC-free systems exist for regular machine cleaning.

### 13.3.2.3 Energy

[155, TWG 2016].

~~The specific energy use of the good practice plant shown in Error! Reference source not found. is 0.8 MWh per tonne pre-product.~~

Reported values for specific energy consumption vary between 0.4 MWh and 0.75 MWh per tonne of substrate or from 10 MWh up to 30 MWh/million m<sup>2</sup> of substrate (all coated slides).

The toluene recovery system (local extraction, steam generation, cooling water pumping) represents a significant share (in some cases close to half) of the total energy consumption of the installation.

In addition to the general techniques (energy-saving lighting, optimisation of pressure level), the main energy-saving techniques identified for the sector are as follows:

- a. heat exchanging in the ventilation systems including the toluene recovery plant, air conditioning, dust extraction lines, trimming line;
- b. reduced air ventilation at idle operation or maintenance;
- c. thermal insulation of tanks and vats with heated liquids (toluene recovery plant adsorbers, hot water tank);
- d. toluene recovery plant with variable frequency drives;
- e. heat recovery from the toluene recovery plant;
- f. air extraction and energy recovery from drying processes.

### 13.3.2.4 Water

[155, TWG 2016].

The toluene recovery process uses some 2–8 kg of steam per kg of recovered toluene. Where, in a 'normal' four press plant, some 7 000 tonnes of toluene are recovered yearly, some 20 000 to 30000 tonnes of water are necessary. Normally this water is reused for cooling purposes or, in the case of new recovery installations, combined with new steam boilers and used again as steam for the toluene recovery. As cooling water, about 30–50 % water can be saved. In



situations where the condensed steam is reused as boiler water, the savings are up to 100 % [4, Intergraf and EGF, 1999, 13, Aminal, et al., 2002].

Two installations reported the following specific water consumption values as follows: 1.146 m<sup>3</sup>/t of product and 10.15 ml/m<sup>2</sup> of product.

Reuse of water was also reported for the cylinder preparation department after proper treatment (sedimentation, filtration, ion exchange).

A typical distribution of water influent and outflow is presented in the diagram of Figure 13.3

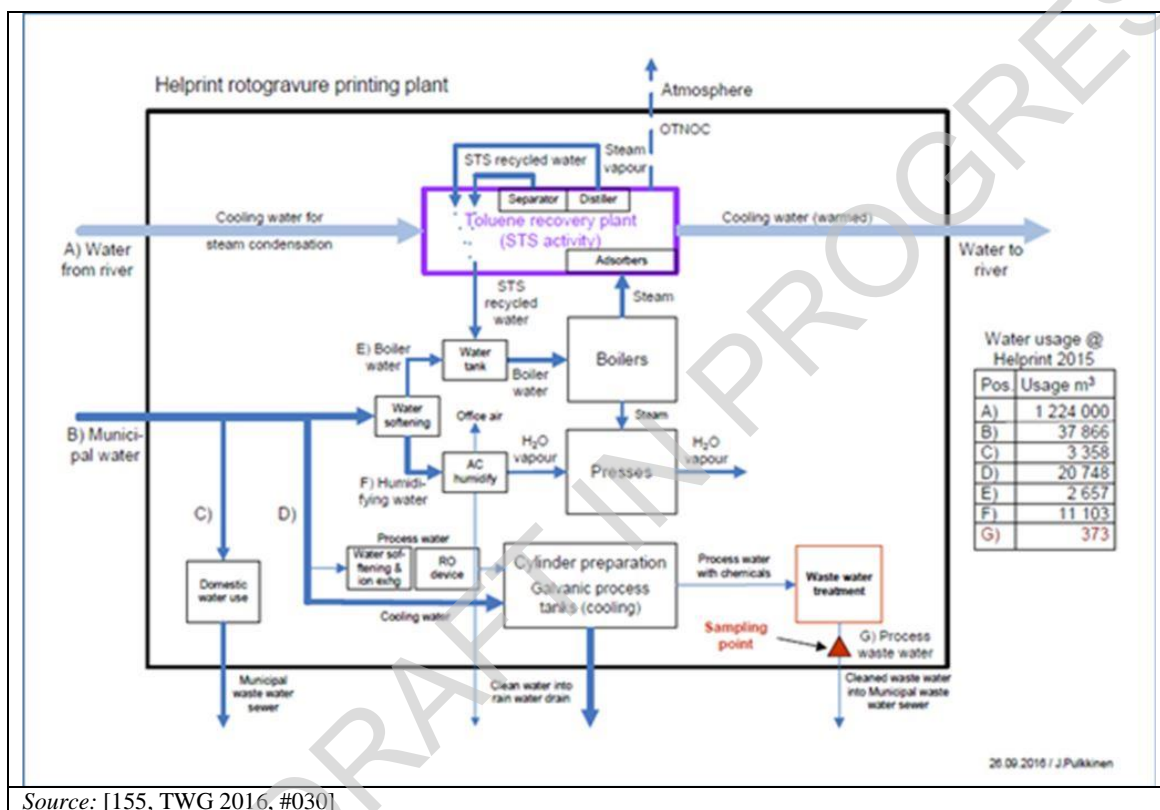


Figure 13.3: Diagram of water use at a publication gravure installation

### 13.3.2.5 Printing substrates and others

No data submitted.

Reported data on annual printing substrate consumption for plants with two or three printing units show a range from 40 000 t up to 90 000 t.

The reported values for paper substrates usage show a variation from 50 kg up to 70 kg of paper per kg of solvent or from 25 kg to 40 kg of paper per kg of ink.

### 13.3.3 Emissions

[78, TWG, 2005] [155, TWG 2016].

All publication gravure plants nowadays have toluene recovery installations. In spite of the toluene recovery, part of the toluene input is still emitted. The abatement equipment has limited efficiency, air from the press room or other department where toluene is used may be ventilated to the outside and also other fugitive emissions may occur [4, Intergraf and EGF, 1999]. However, the residual toluene content in the printed product is by far the most significant source of toluene emissions [18, UBA Germany, 2003].

In order to minimise toluene emissions to air, various techniques have been identified:

- direct piping of inks;
- closed loop distiller system at the toluene recovery for recovering the toluene residue from decanted water;
- use of retention inks;
- connection to the toluene recovery system of all potential toluene-emitting activities/processes: print units, toluene washing machines, viper dryers TWG please confirm technique, press room air at units.

### 13.3.3.1 Total VOC emissions

The reported total VOC emissions values expressed as a percentage of the total solvent input (I) are presented in Figure 13.4.

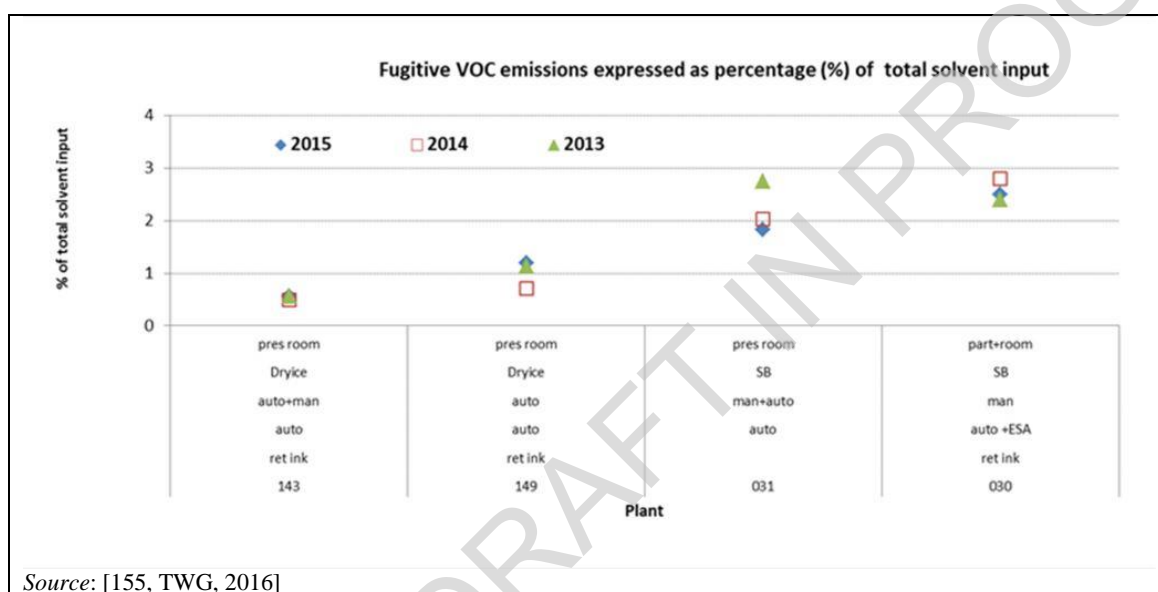


Figure 13.4: Reported values for total VOC emissions expressed as a percentage of the total solvent input for the period 2013–2015

The abbreviations used in Figure 13.4 are explained in Table 13.8.

Table 13.8: Abbreviations used in Figure 13.4 and Figure 13.5

Process	Abbreviation	Additional information
Unit(s) / press room encapsulation	Press room	Pressurised press room and air extraction with subsequent treatment on the toluene recovery unit
	Part+room	Local extraction from printing units and room air ventilation goes to toluene recovery unit
Cleaning material	Dry ice	Removal of dried paint or ink by blasting with dry ice pellets
	SB	Use of solvent-based cleaning agents
Ink piping	auto	Automatic ink piping from containers
Use of retention inks	Ret ink	Retention inks have a modified formulation that slows the film formation and allows evaporation of the toluene over a longer period of time. Use of retention inks could reduce fugitive emissions by 1 % of the total solvent input.

The reported total VOC emission values and contextual information on the layout and operation of the publication gravure plants that submitted data are presented in Table 13.9

**Table 13.9: Reported values of total VOC emissions and contextual information from publication gravure plants**

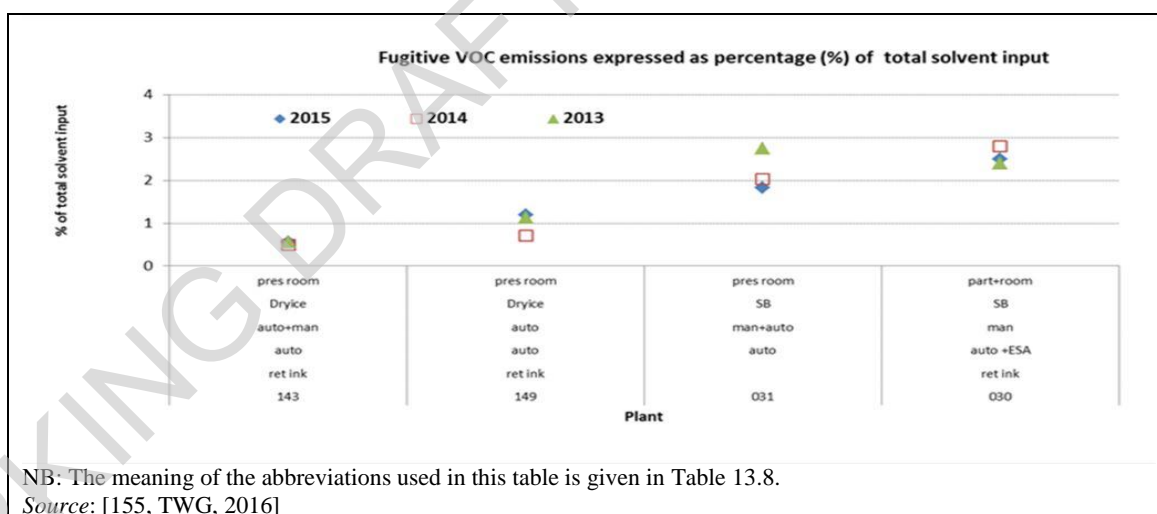
Plant	Use of retention inks	Current layout since year	Enclosure of presses	Room air extraction	Ink piping	Cleaning agents	Press washing system (no. of presses)	Total VOC emissions (% of total solvent input)		
								2015	2014	2013
143	Yes	2000		Yes	Auto	Dry ice	Auto (2) Manual (1)	0.56	0.49	0.55
149	Yes	2009		Yes	Auto	Dry ice	Auto	1.34	0.82	1.23
031		2006		Yes	Auto	SB	Manual (1) Auto (1)	1.89	2.10	2.82
030	Yes	2000	Partial	Yes	Auto + Electrostatic assistance	SB	Manual	2.82	3.09	2.71

Source: [155, TWG, 2016]

As can be seen in Figure 13.4, total VOC emissions as a percentage of the total solvent input are in all cases below 3 % and close to or lower than 1 % when non-solvent-based cleaning agents are used.

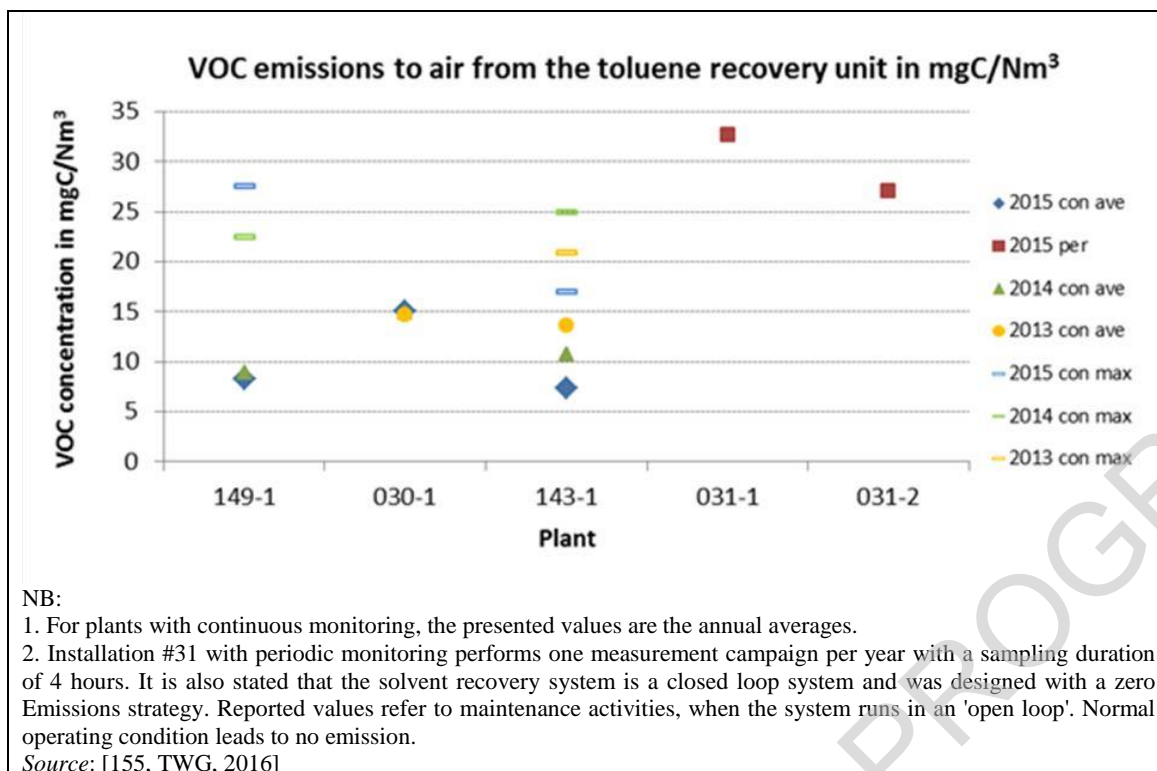
### 13.3.3.2 Fugitive VOC emissions

Reported values for fugitive VOC emissions expressed as percentage of the total solvent input for the reference period 2013–2015 are presented in Figure 13.5.

**Figure 13.5: Reported values for fugitive VOC emissions expressed as a percentage of the total solvent input for the period 2013–2015**

### 13.3.3.3 Emissions in waste gases

All reporting installations operate central toluene recovery systems and at three of them continuous toluene monitoring at the exhaust of the recovery system is performed. The results are presented in Figure 13.6.



**Figure 13.6: Reported VOC emissions values emitted from the toluene recovery unit for the period 2013–2015**

All reported values are below 20 mg C/Nm<sup>3</sup> for continuous monitoring and below 35 mg C/Nm<sup>3</sup> for periodic monitoring.

At EU 25 level for 2000 (according to the RAINS model), NMVOC emissions were 61 kt representing 0.58 % of the total NMVOC emissions. The total activity was 191.48 kt of ink, with an average emission of 0.32 kg NMVOC/kg non-diluted ink which means that this industry already has significantly reduced emissions [81, EGTEI, 2005]:

In the standard situation, 85 % of the total toluene input is recovered and 2–3 % stays in the product; the rest is fugitive. As guidance for standard situations in Flanders, Belgium; there is an emission factor of 0.13 kg fugitive toluene per kg of the total input (new and re-used toluene) [9, VITO, 1998] [14, Aminal, et al., 2002]. The virtual plant in

Figure 13.2 and the plants in show 0.16, 0.10 and 0.06 kg fugitive toluene per kg of the total input, respectively [38, TWG, 2004].

Currently new, modern plants normally emit between 4–10 % of their total solvent input and standard plants between 10–15 %. These modern type presses apply retention inks and all ventilation air (from room and driers) is sent to the solvent recovery installation, even when the press is idle. In the standard situation, only the air from drier ventilation of operational presses is sent to the abatement device [15, CITEPA, 2003] [4, Intergraf and EGF, 1999] [11, IMPEL, 2000].

Of the five gravure printing presses present in the two gravure plants in Flanders, Belgium, the air from the driers is continuously led to the solvent recovery installation, whether the presses are operational or not. From one of these presses, the ventilation air of the press room is also sent to the recovery installation. These plants also apply retention inks and with this

combination of reduction techniques, they can reduce their total toluene emissions to 6.5 % of the total input [13, Aminimal, et al., 2002].

Existing plants in Germany are permitted to emit 10 % of the total toluene input and for new plants this is 5 %. New and existing plants in the Netherlands are allowed to emit 8.5 % of the total toluene input. Dutch plants achieve this by extracting all the air from rooms where toluene is worked and route this to the waste gas treatment system [14, Aminimal, et al., 2002] [12, Netherland, 1996].

Using a range of good practice techniques, emissions for new plants of 4 to 5 % can be achieved, and for existing plants 7.5 to 8.5 % (expressed as a percentage of the total solvent, i.e. toluene input) [38, TWG, 2004].

In the following paragraphs details about the different emission sources are discussed.

#### **Inks**

The toluene concentration of the press ready ink is about 80 wt %, which will all be emitted and most of it recovered, except for about 2–3 % that remains in the product.

Retention inks might reduce fugitive emission by 1 % of the total toluene input [14, Aminimal, et al., 2002] [38, TWG, 2004].

#### **Cleaning agents**

Once the ink is dry, they re-dissolve in toluene, which is therefore used as the cleaning agent. Cleaning may give rise to fugitive emissions of toluene, however, data on quantities are not available. The quantities emitted will be included in the reported fugitive or total emissions. They will depend on the ventilation system and its connection to the solvent recovery systems. Cleaning agents are normally distilled and re-used [4, Intergraf and EGF, 1999] [38, TWG, 2004].

Data on emissions from cleaning agents for water based inks are not available.

#### **Toluene recovery installation**

Toluene is easy to recover. It adsorbs well to activated carbon and is retrieved by heating the carbon with steam. The steam and solvent vapours are condensed and separate almost completely. The toluene is part re-used and part sold back to the ink manufacturers [4, Intergraf and EGF, 1999].

A removal efficiency of 99 % is technically achievable. However, there is a balance with increased energy consumption [14, Aminimal, et al., 2002] [38, TWG, 2004].

#### **Monitoring of emissions to air**

The Solvent Emissions Directive prescribes an emission limit value at the outlet of the waste gas treatment system of 75 mg C/Nm<sup>3</sup> in a 24 hour average and 112.5 mg C/Nm<sup>3</sup> in a 1 hour average. In practice, the 1 hour average is the limiting level for the adsorption cycle. It commonly happens that the 24 hour average is approximately 10–50 mg C/Nm<sup>3</sup>, while the 1 hour average is only met three of four times a day. Monitoring the 1 hour average requires continuous measuring of the emission concentration instead of the cheaper and easier longer time period or volume control.

**13.3.3.4 Waste**

[155, TWG, 2016]

The main categories of produced waste in publication gravure are presented in Table 13.10.

**Table 13.10: Main types of waste generated in publication gravure industry**

Waste type	Source	Final destination	VOC content	Quantity
Paper waste	Production processes	Sold off site	0.5	6–12 % of input quantity
Waste toluene	Air emission abatement	Re-distilled and sold off site	80–100	0.1–0.2 % of input quantity
Slurry toluene	Cleaning of ink tank	Delivered off site as hazardous waste	40–80	0.07–0.1 % of input quantity
Waste ink	Production processes	Delivered off site as hazardous waste	20–85	< 0.1 % of input quantity
Metallic copper	Cylinder preparation – copper plating	Sold off site	0	23–31 t/yr
Solid waste containing Cr(VI)	Cylinder preparation	Delivered off site as hazardous waste containing Cr ions and 35 % sulphuric acid	0	Up to 1 400 kg/yr
De-chroming acid bath electrolyte	Production processes	Delivered off site as hazardous waste	0	4–9 kg/yr
Waste water treatment sludge filter pressed	Waste water (pre)treatment	Delivered off site as hazardous waste	0	Up to 115 t/yr
Cleaning rags from pressrooms	Cleaning processes	Delivered off site as hazardous waste	1	1–2 kg/yr
Carton, paper reel wrappings	Production processes	Delivered off site as non-hazardous waste	0	100–200 kg/yr
Oil and lubricants	Maintenance	Delivered off site as hazardous waste	0	2–4 t/yr
Wood	Material from delivery	Sold off site	0	20–40 kg/yr
Scrap	Maintenance	Sold off site	0	2–25 t/yr

Source: [155, TWG, 2016]

**Paper waste**

Printed paper waste copies contain very small amounts (1 %) of residue toluene, which is released in due course to atmosphere. Printed paper waste is about 50 % of the total paper waste. In relation to the total paper quantity input to the installation, waste paper represents 6–12 % of the total.

**Inks**

In most cases, the work is done with four standard process colour inks and very little mixing of inks takes place. Presses work in shifts and, if at all, are only stopped during the weekends and for public holidays. Only a small proportion of the ink becomes waste and reusing press returns is normal practice [4, Intergraf and EGF, 1999]. Based on data from two installations the waste ink percentage is estimated to less than 0.1 % of the ink input. Waste ink is delivered off site as hazardous waste

Leftover coloured ink is normally mixed with black ink and thus reused, saving on black ink. Waste ink can be distilled to recover the toluene. The distillation sludge, which is about 20 % of the original weight of the waste ink, is disposed of. However, because of the small amounts of toluene recovered, distillation is not often applied because of the relatively expensive equipment needed [4, Intergraf and EGF, 1999].

#### Cleaning materials (wipes, rags)

Used wipes and rags containing ink and toluene residues are dried in drying booths from where the air extraction is directed to the toluene recovery plant. Only very small amounts of residue toluene may remain in the rags after drying.

#### 13.3.3.5 Waste water

Figure 13.7 shows the diagram of waste water generation at a publication gravure installation.

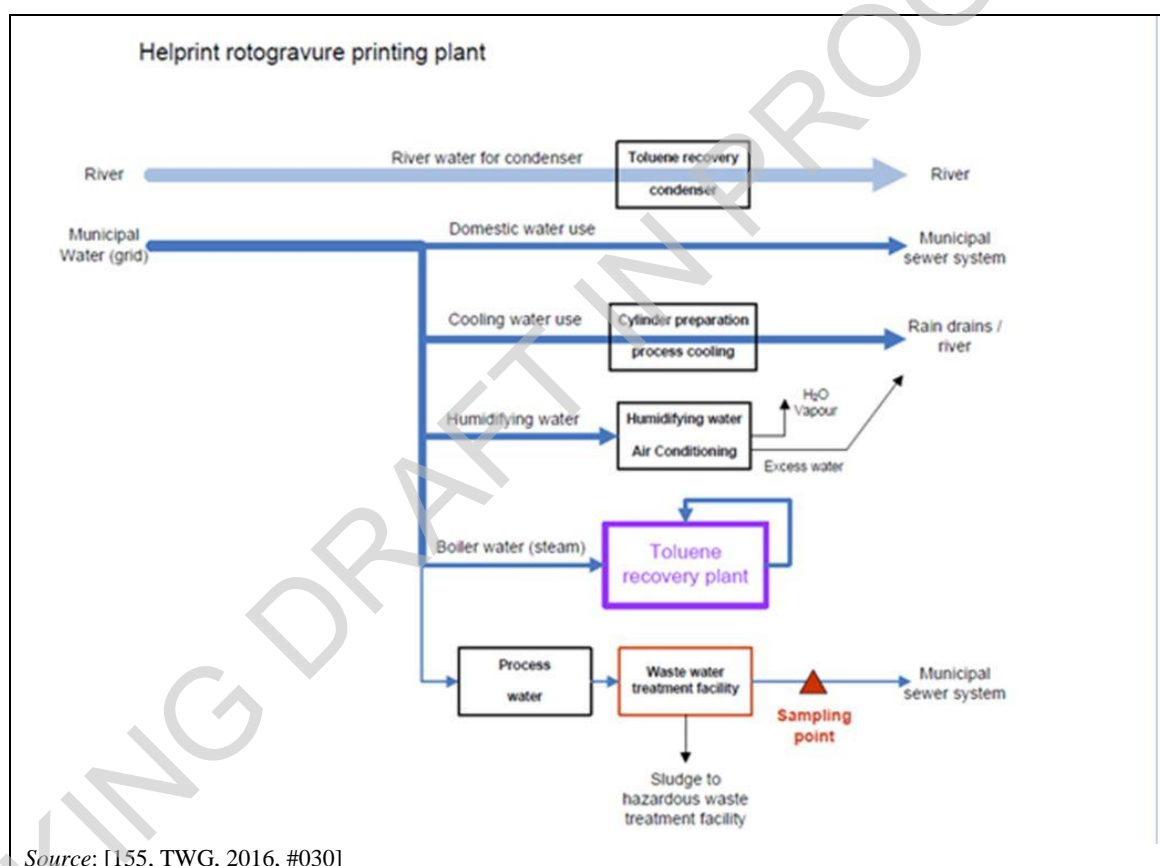


Figure 13.7: Diagram of water use at a publication gravure installation (155, TWG 2016, #030)

Waste water resulting from the dedicated waste water treatment from the cylinder preparation department is directed to the municipal sewer system. This waste water flow represents less than 1 % of the water inlet for the total production needs of the installation (155, TWG 2016, #030, see also Figure 13.6).

Only two data sets with emission monitoring in waste water were submitted with the following values for metal emissions for 2015. The results are presented in Table 13.11.:

Another installation reported waste water effluent only from the sanitary facilities and desludging water from the boiler and the cooling towers. Waste water from the plating department is evaporated to sludge (hazardous waste).

Table 13.11: Reported values of metal concentration from two publication gravure installations for 2015

Installation	030				031			
	Ave.	Max.	Min.	No of samples	Ave.	Max.	Min.	No of samples
Cu	0.39	0.85	0.04	100	0.144	0.538	-	104
Cr(VI)	0.01	0.06	0.01	100	0.278	0.359	-	104
Cr <sub>total</sub>	0.08	0.2	0.01	100	0.003	0.003	-	104

*Source:* [155, TWG, 2016]

The toluene recovery process uses some 2 to 8 kg of steam per kg of recovered toluene. Where in a 'normal' four press plant some 7000 tonnes of toluene are recovered yearly, some 20000 to 30000 tonnes of water are necessary. The condensed steam will contain toluene to its maximum solubility of approximately 0.05 %, in a range of 0.38 – 0.54 g/l. Toluene is on the list II (the EU black list) of substances for water, from Directive 76/464/EEC [4, Intergraf and EGF, 1999] [11, IMPEL, 2000] [38, TWG, 2004].

The condensed steam is stripped of toluene by bubbling air through it; the toluene concentration in the discharged water is approximately 1 to 10 mg/l. The discharge of the above mentioned 'normal' plants will be around 0.1 – 0.3 kg toluene per year [4, Intergraf and EGF, 1999] [11, IMPEL, 2000].



## 13.4 Techniques to consider in the determination of BAT for the publication gravure printing

In Chapter 17, techniques are discussed which might also be applicable to publication gravure. In Table 13.12, the general techniques relevant for publication gravure are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

Table 13.12: Reference to techniques generally applicable to the sector

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### **[Conventional solvent-based inks]**

#### ***Proposed for deletion***

*Conventional techniques have been deleted if they can no longer be considered BAT. This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumptions or emissions.*

**Description:** ~~Conventional inks used in publication gravure, are toluene-based. In the printing plant, inks are significantly thinned before being used. The toluene concentration of the press ready ink is in the range of 70–80 wt %.~~

**Achieved environmental benefits:** ~~No information provided.~~

**Cross media effects:** ~~No information provided.~~

**Operational data:** ~~No information provided.~~

**Applicability:** ~~No information provided.~~

**Economics:** ~~With a high press speed, solvent recovery is possible.~~

**Driving force for implementation:** ~~Most stable process. Easiest de-inking of printed paper for recycling.~~

**Example plants:** ~~No information provided.~~

**Reference literature:** [18, UBA Germany, 2003] [78, TWG, 2005]

### 13.4.1 Material-based techniques [~~Substitutes for conventional solvent-based inks~~]

#### ~~[Water-based alternatives]~~

*Proposed for deletion as not applicable in the sector*

~~**Description:** Water based inks only contain some organic solvents. Conventional water based inks rely on relatively high acid resins for water dispersibility; more recently developed inks are based on water dispersible polyester resins. The latter ones do not need neutralising agents such as ammonia or amines to maintain their dispersibility properties.~~

~~**Achieved environmental benefits:** The currently applied inks are based on toluene and huge reductions in the use of toluene can, theoretically, be achieved. However, all publication plants are equipped with waste gas treatment systems and toluene emissions are already significantly reduced. An LCA study carried out in Germany has not given any clear indication that water based gravure inks can be considered a cleaner technology solution for existing plants; rather the opposite.~~

~~Cleaning of water based inks can be done with water. However, if the ink or varnish dries, then solvents have to be used.~~

~~**Cross-media effects:** The energy consumption for forced drying of the water based ink is higher and more waste is generated.~~

~~It is difficult to de ink paper products and wastes in normal de inking plants. This inhibits the recycling of products.~~

~~**Operational data:** The print quality with water based inks is lower than with conventional inks.~~

~~**Applicability:** They are not applied in publication gravure printing processes because of practical problems.~~

~~**Economics:** For changing from solvent based inks to water based inks, high costs are involved. For new plants or presses, investment costs for applying water based inks are more or less the same as for solvent based inks.~~

~~The cost for retrofitting one publication gravure press is EUR 1 million. At the start, operational costs are 20 % higher than for conventional printing because of the learning period, however, in the end they will be more or less equal.~~

~~In addition, productivity because of lower press speeds and print problems on wider web widths is only about 70 % of normal.~~

~~**Driving force for implementation:** No information provided.~~

~~**Example plants:** RotoSmeets, Deventer, the Netherlands, is one of several publication gravure plants that experimented with water based inks, without achieving acceptable results.~~

~~**Reference literature:** [8, Nordic Council of Ministers, 1998] [4, Intergraf and EGF, 1999] [11, IMPEL, 2000] [14, Aminal, et al., 2002] [18, US EPA et al., 2003, 38, TWG, 2004]~~

### 13.4.1.1 Use of retention inks

#### Description

Retention inks have a modified formulation that slows the film formation and allows evaporation of the toluene over a longer period of time. The result is that a higher percentage of the toluene can be expelled directly into the ink drying unit and can be captured. Less toluene will remain in the product.

#### Achieved environmental benefits

The remaining toluene load in the product, measured directly at the delivery area of the press, can be reduced by 30–50 %.

Diffuse emissions can be reduced by approximately 1 % of the total input. This corresponds to a reduction of 20 % of the total emissions from a good practice gravure plant (where total emissions are 5–6 % of the total input, including from waste gas treatment: input is as defined in the IED) [18, UBA Germany, 2003].

These benefits can only be achieved where the waste gas from the dryers are extracted and treated.

#### Cross-media effects

Where adsorption is used, more energy is reported to be needed to desorb the higher load of toluene produced from the dryers.

#### Operational data

No information provided.

#### Applicability

Applicable for all publication gravure processes, except where special inks are required that do not have a retention ink counterpart.

In the EU-15, 70 % of the publication gravure inks used are now retention inks, and in Germany, 100 %.

#### Economics

The price of retention inks is the same as conventional inks; however, less ink is needed (although this is not an ink reduction technique).

The savings for each kg of toluene recovered are about EUR 0.50.

#### Driving force for implementation

Less toluene in the final product.

#### Example plants

Large number of plants throughout Europe.

#### Reference literature

[4, Intergraf and EGF, 1999] [18, UBA Germany, 2003] [14, Aminal, et al., 2002] [38, TWG, 2004] [78, TWG, 2005]

## 13.4.2 Waste gas extraction and treatment techniques

### 13.4.2.1 Increased temperature in the press room

#### Description

With higher temperatures in the press room, more toluene will evaporate from the residues in the printed product. A prerequisite for this technique to be effective is that the air in the press room is extracted and that the extraction system is connected to a waste gas treatment system.

#### Achieved environmental benefits

Reduction of fugitive emissions stemming from the printed products. In this way, fugitive emissions are reported to be reduced by approximately 1 %.

#### Cross-media effects

Energy consumption may be higher if the press room requires heating.

#### Operational data

Applying the mass balance of the virtual gravure plant in Section 13.3.3.1 with a total of about 352 t of fugitive emissions, approximately 3.5 t could be saved by additional extraction from the paper web. The total residual solvent, however, is 43.3 t. Consequently, the higher press room temperature supposedly reduces the solvent content in the product by more than 8 %. Tests in a rotogravure plant in north Germany, raising the drying temperature from about 40 to 90 °C has proved to be unable to achieve a reduction of this extent.

#### Applicability

No information provided.

#### Economics

Possible higher running costs. These may be offset as the savings for each kg of toluene recovered are about EUR 0.50.

#### Driving force for implementation

No information provided.

#### Example plants

Not known to be applied in EU-15.

#### Reference literature

[14, Aminal, et al., 2002, 38, TWG, 2004] [78, TWG, 2005]

### 13.4.2.2 Increasing drying time

#### Description

Increasing drying time and maintaining the same speed can be achieved by increasing the length of the dryer.

#### Achieved environmental benefits

With a prolonged retention time, more toluene will have the time to evaporate inside the dryer which will be routed to the waste gas treatment system.

#### Cross-media effects

Increased capacity of the dryers will increase energy consumption. Noise levels might also increase.

#### Operational data

No information provided.

**Applicability**

Only applicable to new presses; retrofit is not possible.

**Economics**

The savings for each kg of toluene recovered are about EUR 0.50.

**Driving force for implementation**

No information provided.

**Example plants**

No information provided.

**Reference literature**

[4, Intergraf and EGF, 1999] [38, TWG, 2004]

**[Discontinuous air extraction from the driers]**

*Proposed for deletion –see chapter 13.4.2.3*

**Description:** When the press is running, the air in the driers is extracted and routed to the waste gas treatment system (i.e. only the air from the driers, and only when the press is running). The press is not enclosed and the amount of ventilation air around the press that is routed through the driers is small. The ventilation air in the press room is not routed through the waste gas treatment system.

**Achieved environmental benefits:** A level of fugitive emissions of 15–20% of the total toluene input can be achieved. The air from the driers has a high load of toluene, which makes the adsorption of toluene very efficient. Because the capacity of the waste gas treatment system is laid out only for the air coming from the driers, the system is relatively small and can achieve a good balance between reduction of VOCs and use of energy.

**Cross-media effects:** High levels of VOC around the press and in the press room might be found. Extra ventilation because of workers health and safety might be necessary. Noise levels might increase.

**Operational data:** No information submitted.

**Applicability:** This technique is now outdated as it fails to meet the requirements of the IED.

**Economics:** The savings for each kg of toluene recovered are about EUR 0.50.

**Driving forces for implementation:** Workplace health and safety.

**Example plants:** No information submitted.

**Reference literature:** [4, Intergraf and EGF, 1999, 14, Aminal, et al., 2002, 38, TWG, 2004]

**[Continuous air extraction from the dryers]**

*Proposed for deletion –see chapter 13.4.2.4*

**Description**

The air in the dryers is extracted and routed to the waste gas treatment system as in Section 2.4.3.3.3 above. However, in addition to when the press is running, the dryer air is also extracted and treated when the press contains ink, but is otherwise idle. The press is not enclosed and the amount of ventilation air around the press that is routed through the dryers is

small. However, it is significantly more than with only discontinuous air extraction as addressed in Section 0. The ventilation air in the press room is not routed through the waste gas treatment system.

**Achieved environmental benefits**

Lower toluene emissions than in Section 0.

**Cross-media effects**

Noise levels might increase and increased energy is required for the extraction and recovery of toluene. Air with small concentrations of toluene is routed through the waste gas treatment system. Generally, this results in lower efficiency of the recovery installation.

**Operational data**

No information provided.

**Applicability**

No information provided.

**Economics**

The savings for each kg of toluene recovered are about EUR 0.50. Running costs are higher than those noted in Section 0.

**Driving force for implementation**

Implementation of IED. Occupational health and safety.

**Example plants**

No information provided.

**Reference literature**

[38, TWG, 2004]

**~~[Enclosed press and ventilation air is routed to the waste gas treatment system discontinuously]~~**

*Proposed for deletion –see chapter 17.10.2*

**Description**

The press is completely enclosed. The ventilation air inside the enclosure is extracted via the dryers and routed to the waste gas treatment system discontinuously, i.e. only when the press is running (as in Section 2.4.3.3.3). Normally there is negative pressure inside the enclosure to prevent air escaping to the press room.

**Achieved environmental benefits**

Lower toluene emissions and lower energy consumption for extraction than in Section 0.

**Cross-media effects**

No information provided.

**Operational data**

No information provided.

**Applicability**

No information provided.

**Economics**

The savings for each kg of toluene recovered are about EUR 0.50. Capital costs are higher than those noted in Section 0.

**Driving force for implementation**

Implementation of IED. Occupational health and safety.

**Example plants**

No information provided.

**Reference literature**

[38, TWG, 2004]

**[Enclosed press and ventilation air is routed to the waste gas treatment system continuously]**

*Proposed for deletion –see chapter 17.10.2*

**Description**

The press is completely enclosed. The ventilation air inside the enclosure is extracted via the dryers and routed to the waste gas treatment system continuously; including when the press contains ink but is otherwise idle (i.e. as Section 2.4.3.3.4, but ventilation air is also extracted to recovery). Normally there is negative pressure inside the enclosure to prevent air escaping to the press room.

**Achieved environmental benefits**

Total toluene emissions can be reduced to 5–8.5 % of the total toluene input.

**Cross-media effects**

Air with small concentrations of toluene is routed through the waste gas treatment system. Generally, this results in lower efficiency of the recovery installation. Increased energy consumption to Section 0.

**Operational data**

In the Netherlands, all large plants have been applying this technique since 1996.

**Applicability**

Commonly applied.

**Economics**

To install a new press, additional costs for enclosure and continuous routing of the solvent laden air through a waste gas treatment system adapted to the larger airflow is some EUR 0.5 million. The additional operational costs are about EUR 100 000 per year per press.

The savings for each kg of toluene recovered are about EUR 0.50.

Retrofitting non-encapsulated presses in combination with a small capacity waste gas treatment system is prohibitively expensive.

**Driving force for implementation**

Implementation of IED. Occupational health and safety.

**Example plants**

Two Flemish printing plants and all relevant Dutch plants.

**Reference literature**

[4, Intergraf and EGF, 1999] [12, Netherland, 1996, 38, TWG, 2004]

**13.4.2.3 Discontinuous air extraction from the press, the dryers and the press room**

See also Section 17.10.2

**Description**

The extracted air from the press room is routed to the waste gas treatment system, along with the air from the dryers and from the encapsulated press. However, the air is extracted only when the presses are running.

There are facilities where personnel controlling the printing process are situated in separate control rooms. In these situations, the separate press room where the machines are sited can be seen as the encapsulation of the press. The air from this room is extracted and routed to the waste gas treatment system. ~~This situation may be similar to that described in Section 2.4.3.3.5.~~

**Achieved environmental benefits**

Low toluene emissions.

**Cross-media effects**

Increased energy consumption for extraction and toluene recovery.

**Operational data**

All publication gravure plants are equipped with a waste gas treatment system; however, the capacity of the existing system might not be sufficient to also deal with the airflow from the press room.

**Applicability**

No information provided.

**Economics**

The savings for each kg of toluene recovered are about EUR 0.50.

**Driving force for implementation**

~~Implementation of IED.~~ Occupational workplace health and safety.

**Example plants**

No information provided.

**Reference literature**

[38, TWG, 2004]

**13.4.2.4 Continuous air extraction from the press, the dryers and the press room**

See also Section 17.10.2

**Description**

The air from the dryers and from the encapsulated press is routed to the waste gas treatment system continuously. In addition the extracted air from the press room is also diverted to the recovery plant.

There are facilities where personnel controlling the printing process are situated in separate control rooms. In these situations, the separate press room where the machines are sited can be seen as the encapsulation of the press. The air from this room is extracted and routed to the waste gas treatment system. This situation may be similar to that described in Section 2.4.3.3.6.

**Achieved environmental benefits**

Total emissions can be reduced to a level of approximately 5–8.5 % of the total toluene input. Together with applying retention inks, an emission level of 6.5 % of the total input can be achieved by the two Flemish printing plants.



**Cross-media effects**

No information provided.

**Operational data**

All publication gravure plants are equipped with a waste gas treatment system, however, the capacity of the existing system might not be sufficient to also deal with the airflow from the press room.

For the two Flemish plants, it is thought that this technique shows a good balance of an achievable emission level of 6.5 %, avoiding excessive energy consumption.

**Applicability**

This technique is commonly applied in new plants. In the Netherlands, all large plants have been applying this technique since 1996. Retrofit might be prohibitively expensive because it requires almost a complete replacement of the gas treatment system and new piping work needs to be installed.

**Economics**

Extra investment cost, compared to the situation where only the dryers are connected to the waste gas treatment system, is about EUR 0.5 million per press. Additional operational costs are about EUR 100 000 per year per press.

The savings for each kg of toluene recovered are about EUR 0.50.

**Driving force for implementation**

Implementation of IED. Occupational workplace health and safety.

**Example plants**

Two plants in Flanders, Belgium, and all large Dutch plants.

**Reference literature**

[14, Aminal, et al., 2002] [12, Netherland, 1996, 38, TWG, 2004]

**13.4.2.5 Internal concentration of solvents (Closed air loop ventilation)**

For a general description see also Section 17.10.3.2

**Description:** The exhaust air from the waste gas treatment system is returned to the driers or the press room. This requires a waste gas treatment system with a much higher capacity than normal. The frequency of the adsorption/desorption cycle is very short to achieve very low toluene levels in the recycled air stream. Before sending the exhaust air stream to the building again, the air has to be cooled.

**Achieved environmental benefits:** Depending on the size of the press, the total emission might be reduced to 20 - 75 t/yr.

**Cross-media effects:** A higher frequency of the adsorption/desorption cycle creates more waste water and requires more use of energy. More energy is also needed because the capacity of the waste gas treatment system is higher. However, several energy reduction or re-use options are commonly installed.

**Operational data:** No information submitted.

**Applicability:** Applicable to new presses in combination with a new waste gas treatment system. The technique is also applicable to existing presses when a new waste gas treatment system has to be installed. Retrofitting an existing waste gas system is too expensive.

A new three metre press in a plant in the Netherlands, including a new waste gas treatment system, applying closed air loop ventilation achieved a toluene emission reduction of 75 t/yr. For the two Flemish plants, with presses which are smaller and slower, the achievable reduction may be 20 t/yr for each press; however, the technique is not installed at these plants because the costs for retrofit are too high.

**Economics:** For a three metre press, additional investment costs, on top of the costs for a new waste gas treatment system, are EUR 5 million. The operational costs are the same when energy saving techniques are installed. Costs per tonne of avoided toluene emission are about EUR 10000, based on a loan for a period of 10 years with an interest rate of 7 % (1999).

The savings for each kg of toluene recovered are about EUR 0.50.

**Driving forces for implementation:** Implementation of IED; workplace health and safety.

**Example plants:** Etten Leur, the Netherlands.

**Reference literature:** [18, UBA Germany, 2003] [14, Aminal, et al., 2002] [4, Intergraf and EGF, 1999, 38, TWG, 2004]

### 13.4.2.6 Air knives on the printed web

For a general description see also 0

#### **Description**

Air knives prevent the web from carrying solvent-laden air out of the dryers.

#### **Achieved environmental benefits**

Fugitive solvent emissions are reduced.

#### **Cross-media effects**

Noise levels might increase along with an increase in energy consumption.

#### **Operational data**

No information provided.

#### **Applicability**

Applicable to webfed printing processes using forced air drying systems.

#### **Economics**

Relatively low cost; increased energy costs.

#### **Driving force for implementation**

Implementation of IED. Occupational health and safety.

#### **Example plants**

This technique is commonly applied in publication gravure.

#### **Reference literature**

[4, Intergraf and EGF, 1999]

## 13.4.3 Cleaning techniques

### 13.4.3.1 In-press cleaning of printing cylinders

#### **Description**

The printing cylinders in publication gravure presses are cleaned automatically in the press. The air is extracted to the toluene recovery system.

**Achieved environmental benefits**

No information provided.

**Cross-media effects**

No information provided.

**Operational data**

Applied in publication gravure.

**Applicability**

Only for new presses.

**Economics**

No information provided.

**Driving force for implementation**

No information provided.

**Example plants**

No information provided.

**Reference literature**

[4, Intergraf and EGF, 1999]

**13.4.3.2 Cleaning materials (wipes, rags)**

Used wipes and rags containing ink and toluene residues are dried in drying booths from where the air extraction is directed to the toluene recovery plant. Only very small amounts of residue toluene may remain in the rags after drying.

WORKING DRAFT IN PROGRESS

## 14 COATING OF FURNITURE AND WOOD MATERIALS

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [57, VDI, 2005] [78, TWG, 2005] [162, COM, 2014].

### 14.1 General information on the coating of furniture and wood materials

Wood is a natural raw material characterised by its inhomogeneity and anisotropy, and which displays irregular properties in terms of surface structures, the varying contents of different substances (e.g. waxes, water, resins), and variable electrical resistance. Wood fibres often have the characteristic that they swell-up and become erect under the influence of liquids (in particular, with water). Wooden surfaces are coated, in order to conserve or strengthen the colour, surface structure and/or porosity. The coating is applied to provide, for example, resistance against:

- chemical impacts;
- mechanical stress;
- climatic impacts;
- staining.

Currently, the wood and furniture industry is facing new market requirements, as complicated product geometry and higher qualities (e.g. colour variety, new surface effects) are demanded. To meet these expanding requirements, spray application techniques are increasingly being utilised.

This industry is characterised by a strong predominance of medium-sized companies, with 75 % of enterprises having less than 100 employees. ~~In Germany, the following enterprises exist:~~

- ~~• 45000 joineries (with an average of 4.5 employees)~~
- ~~• 1500 wood and wooden furniture paintshops (with an average of 75 employees)~~
- ~~• approx. 8 very large enterprises with more than 1000 employees.~~

~~In the German wood and furniture industry, more than 80000 tonnes of paints were processed in 1999, with approx. 60 % being used in industrial applications and the remaining 40 % being consumed by handicraft enterprises. Over the past few years, the processed amounts of paints have slightly decreased, and it is expected that this trend will continue in the future. This is due to a number of reasons, including the shifting of production capacities to Eastern Europe, the increasing utilisation of plastic films for the surface design, a continuing reduction of the coating layer thickness and the increasing use of paints with high solids content.~~

Germany, Italy, Poland, France and the UK account for over two thirds of all EU furniture production. Half of all the European furniture manufacturing companies are located in these countries, and together they employ around 60 % of the European sector workforce [162, COM, 2014].

Table 14.1: The furniture sector in the EU-28

Enterprises	2003	2004	2005	2006	2007	2008	2009	2010	2011
	134 557	134 879	134 577	135 266	135 902	130 750	126 061	131 077	126 000
Employees	1 178 781	1 191 393	1 162 084	1 144 611	1 151 988	1 096 161	993 919	937 247	919 311
Share of production in total manufacturing (%)	1.8	1.9	1.8	1.8	1.8	1.7	1.7	1.6	1.4

Source: [162, COM, 2014]

Table 14.2: Furniture production in the EU-28 in 2012 [162, COM, 2014]

	Million EUR	Share of EU total	Average yearly growth rate 2003–2012
Germany	17 738	21 %	1.5 %
Italy	15 950	19 %	-2.1 %
Poland	8 323	10 %	7.4 %
France	7 929	9 %	0.2 %
United Kingdom	7 022	8 %	-2.5 %
Spain	4 611	5 %	-4.8 %
Sweden	3 021	4 %	2.4 %
Denmark	2 147	3 %	-2.2 %
Netherlands	2 119	3 %	-0.7 %
Austria	2 115	3 %	-0.4 %
Belgium-Lux	1 953	2 %	-0.6 %
Romania	1 594	2 %	6.3 %
Czech Republic	1 459	2 %	1.5 %
Portugal	1 354	2 %	-0.4 %
Lithuania	1 090	1 %	11.2 %
Hungary	1 017	1 %	1.8 %
Finland	929	1 %	-2.6 %
Slovakia	928	1 %	6.6 %
Slovenia	619	1 %	-3.4 %
Greece	532	1 %	-7.9 %
Ireland	376	0 %	-3.5 %
Estonia	373	0 %	2.0 %
Croatia	369	0 %	1.8 %
Bulgaria	268	0 %	2.6 %
Latvia	188	0 %	-0.3 %
Cyprus	82	0 %	-4.1 %
Malta	41	0 %	-3.4 %
<b>EU-15</b>	<b>67 796</b>	<b>81 %</b>	<b>-1.0 %</b>
<b>EU-13</b>	<b>16 351</b>	<b>19 %</b>	<b>5.1 %</b>
<b>EU-28</b>	<b>84 147</b>	<b>100 %</b>	<b>-0.1 %</b>

Source: [162, COM, 2014]

Over the last few years, the level of automation of paint application in the furniture industry has increased significantly, mainly due to increasing quality, efficiency and environmental requirements.

A variety of materials are processed and coated in the wood and furniture industry. These can be distinguished in a number of fields of applications:

- exterior construction, fittings and furniture;
- interior construction, fittings and furniture;
- commercial and public applications, e.g. schools;
- domestic applications;
- wet applications, e.g. for swimming pools, saunas, kitchen and bathrooms.

## 14.2 Applied processes and techniques in the coating of furniture and wood materials

The application of coating materials for wood and wood materials involves:

- pretreatment of the wood surface;
- application of a base coat;
- application of a topcoat;
- application of the paint;
- flashing-off and drying/curing.

Depending on the desired surface structure (i.e. open or closed cell pore structure), different paint systems may be used. If the wooden grains need to be visible, e.g. for solid wood or veneer, uncoloured paints (i.e. clear coats), oils and waxes are used. For example, medium dense fibre (MDF) panels are coated with pigment paints of the desired colour. If pigment paint systems are used, a barrier layer is applied before the base coat, which restricts permeation of paint to the wooden sub-surface and allows a more uniform paint layer to be applied.

### 14.2.1 Pretreatment of the wood surface

Due to irregular growth and the varying surface structure, and because of the differing content of certain substances such as resin or wax, proper pretreatment of the surface to be coated is essential. This pretreatment can address different aspects of the wood, such as the existing surface flatness, removal of working marks, treatment of colour differences, unevenness, fibre erections, cracks, boughs, as well as wood moisture. Typical pretreatment techniques include:

- mechanical pretreatment, e.g. sanding;
- colouring methods, such as:
  - staining,
  - glazing,
  - bleaching.

For some special kinds of wood, it is necessary to use chemical cleaning processes which utilise soap solutions, ammonia or organic solvents, together with a sanding technique for the disposal of paint incompatible wood substances such as resin and wax.

#### **Sanding**

Usually for ideal paint results, wood and wooden base materials need an intermediate sanding to be applied after the application of a base coat or after staining or the application of other paint layers, since an erection of wood fibres is caused by the interaction with fluids. This kind of napping of the wooden surface is especially significant when water-based paint systems are used.

#### **Staining**

The aim of staining is to change the colour of the wood to a darker colouring. The wooden structure and the pore structure respectively remain the same. Depending on the applied type of staining, the drying time varies considerably. Stains are suspensions of pigments or solutions of dyes in water or organic solvents. The most commonly applied stain is solvent-based. If

chemical stains such as, for example, one-component positive stains are used; longer residence times have to be taken into account. If water-based stains are processed, the swelling and roughening of the wood (napping) has to be allowed for. Also combinations of water-dilutable organic solvents and water can be used (combi-stains). The traditionally applied stain is a water-based material. The compositions of some different types of stains are listed in Table 14.3 below.

**Table 14.3: Composition of different types of wood stains**

	Water content (%)	Content of organic solvents (%)	Proportion of pigments (%)
Water-based stain	Up to 95	0	Up to 15
Solvent-based stain	0	85–95	5–15 *
Combi-stain	65–70	25–30	5
* In some roller applications, the proportion of pigments may be up to 15 % Source: [38, TWG, 2004]			

Application is either carried out manually (with sponge, brush, rolls, spraying) or is automated (automated spray applications, rolling, foam rubber rolls). Subsequent drying takes place at ambient temperatures or in convection dryers, flat dryers or jet dryers.

### Glazing

Modern glazes are high liquid wood covers based on lacquer resins. The materials achieve a good penetration of the wood and often contain water repellents and fungicide ingredients to improve the wood. They may be colourless or may be pigmented with different colourings. Different materials are used for outdoor and indoor usage. Glazes without fungicides, as well as colourless wood glazes, are only suitable for indoor usage.

### Bleaching

In general, bleaching brightens the wood colour. Sometimes it is necessary to bleach several times, for example if maple is used. For bleaching, hydrogen peroxide (30 – 35 %) and several additives or radiation are used. The impact time has to be adjusted to the desired effects. As bleaching splits off oxygen, a sufficient drying is necessary in order to avoid blistering. Bleaching is also used for wood with non-light-resistant colourings such as cherry or rosewood. After bleaching, staining with highly light resistant pigments is used to reproduce the original wood colouring. If PUR coating systems are used, the curing agent has to be peroxide-resistant.

## 14.2.2 Application of a base coat

Base coat material needs to be suitable for sanding down. Application techniques include:

- spraying (manually or automatically; conventional, airless, air-assisted airless (so-called 'airmix') and electrostatically assisted);
- casting;
- rolling (e.g. using a UV curing lacquer suitable for rolling);
- dipping (only for special workpieces).

After drying of the pretreatment stage, sanding (with material of an appropriate grain size) takes place before a colourless base coat is applied. Afterwards the surface is sanded again before a topcoat is applied. In some cases, a wooden structure is printed directly onto the base coat. As the substrate, mainly simple veneers are used or alternatively, the surface to be coated may already incorporate a coloured base coat/stopper.



### 14.2.3 Application of a topcoat

For the coating of wood and wood materials, paints, foils or other panel-like coating materials, as well as textiles or leathers are used. Some specific coatings are:

- nitro cellulose paint (NC) sometimes called cellulose nitrate paint (CN);
- acid curing paints;
- polyurethane paints (PUR);
- unsaturated polyester paints (UP):
  - open-cell UP materials,
  - thick-film layer systems;
- water-based paints;
- powder coatings;
- alkyd paints/glazes;
- combined/mixed paint systems;
- waterborne UV lacquers;
- 100 % UV lacquers.

The same application techniques are used as described in Section 14.2.2.

Table 14.4 itemises the main properties of the most commonly used wood stains and paints.

**Table 14.4: Overview of the properties of wood stains and paints**

Wood stain or paint type	Proportion of solvent (%)	Proportion of water (%)	Components	Type of reaction	Catalyst	Remarks
<b>Wood stain</b> <ul style="list-style-type: none"> <li>• solvent-based               <ul style="list-style-type: none"> <li>– type a) 70</li> <li>– type b) 25–30</li> <li>– type c) 0</li> </ul> </li> <li>• water-based</li> </ul>	95 70 25–30 0	0 25–30 70–80 85–95				Organic solvents; water-dilutable solvents; combi-wood stain; water-dilutable solvents; napping of wood
<b>NC paint (CN paint)</b> <ul style="list-style-type: none"> <li>• uncoloured</li> <li>• pigmented</li> </ul>	Approx. 75 Approx. 60	0 0	Collodium wool (cellulose nitrate)	Physical drying		Surface resistance with limited usability
<b>Acid curing paint</b> <ul style="list-style-type: none"> <li>• two-component; uncoloured</li> <li>• two-component, pigmented</li> <li>• one-component; uncoloured</li> </ul>	40–50 20–30 20–30		Alkyde-melamine urea resins polyoles	Forced drying	Acid	Older paint systems emitted formaldehyde; high resistance
<b>PUR paint</b> <ul style="list-style-type: none"> <li>• uncoloured</li> <li>• pigmented</li> <li>• medium solid; uncoloured</li> </ul>	65–70 36–60 40–50	0 0 0	Isocyanates; acrylates; polyesters	Addition reaction (physico-chemical)		Generally two-component materials; high resistance

Wood stain or paint type	Proportion of solvent (%)	Proportion of water (%)	Components	Type of reaction	Catalyst	Remarks
<b>UP paint</b> <ul style="list-style-type: none"> <li>conventional</li> <li>containing paraffin</li> <li>free of paraffin</li> <li>UV curing <ul style="list-style-type: none"> <li>rolling lacquer</li> <li>stopper</li> </ul> </li> <li>UP-spraying paint <ul style="list-style-type: none"> <li>uncoloured</li> <li>UV curing</li> </ul> </li> </ul>	Approx. 35 (15) Approx. 35 (15) Approx. 35 (15) Approx. 35 (15) Approx. 35 (15) Approx. 20 (20) Approx. 20 (10) 65–70 65–70	0 0 0 0 0 0 0	Polyester, unsaturated (organo-metallic materials)	Polymerisation <ul style="list-style-type: none"> <li>heat</li> <li>radiation</li> </ul>	Organic peroxides    UV radiation; Photo-initiator	Component systems; for infrared curing UP coatings, pre-drying and curing times have to be allowed for
<b>Acrylate paint</b> <ul style="list-style-type: none"> <li>UV curing <ul style="list-style-type: none"> <li>rolling lacquer</li> <li>spraying paint open cell structure</li> </ul> </li> <li>electron beam curing</li> </ul>	2–40 2–10 65–70  2–5		Polyacrylate, unsaturated	Electron beam	Photo-initiator	
<b>Water-based paint</b> <ul style="list-style-type: none"> <li>conventional drying</li> <li>UV curing</li> <li>PUR, two-component</li> </ul>	5–7 Approx. 2 Approx. 9	60–65 58–60 60–65		Physically drying; polymerisation; addition reaction	UV radiation	Napping of the wood; longer drying times; possibly application of UV base coat followed by a water-based paint application; UV curing water-based paint is becoming more and more significant. UV coating can only be applied where flat pieces can be coated separately and coating is done before the piece of furniture in assembled

Wood stain or paint type	Proportion of solvent (%)	Proportion of water (%)	Components	Type of reaction	Catalyst	Remarks
<b>Powder coating</b> <ul style="list-style-type: none"> <li>• conventional drying</li> <li>• UV curing</li> </ul>	0	0	Epoxy resins Polyester-acrylate resins	Addition and condensation	UV radiation	Powder coatings with conventional convection drying are not suitable for the coating of wood at present. Application systems exist only for the coating of MDF
<b>Alkyde resin paints</b>	10–80	0	Alkyde resins	Oxidation in air physico-chemical drying	Organometallic compounds	Organic solvents

NB: Data in brackets means the solvent content emitted as % of the coating.  
Source: [13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

#### 14.2.4 Application of the paint

The following application techniques are used for wood and wood materials:

- painting, rolling;
- manual spraying (partly also using electrostatically assisted processes);
- automated spraying (partly also using electrostatically assisted processes);
- automated spraying with or without the recycling of overspray (partly also using electrostatically assisted processes);
- rolling;
- vacumat technique;
- filling with stoppers;
- curtain coating;
- dipping/flooding;
- printing.

Besides manual spray applications, spraying installations or spraying machines equipped with two-component dispensing units are in use in the furniture industry. Table 14.5 lists the achievable application efficiency factors.

Table 14.5: Achievable application efficiency factors

Application technique	Efficiency factor <sup>(1)</sup>	Remarks
Painting, rolling	95–100	Reduced uniformity of surface
Spraying, conventional	30–60	High amount of overspray
Spraying, HVLP	40–75	Application of low viscous wood stains, increasing use also for other paint systems
Hot spraying	40–60	Application of paints with a high solids content, also applicable for hot wax spraying
Airless spray application	40–75	Bundling of sprayed material
Air-assisted airless technique	35–50	Bundling of sprayed material
Spraying, electrostatically assisted wet lacquer	50–70	Electrical conductivity has to be considered
Spraying, electrostatically assisted powder	80–95	Electrical conductivity has to be considered. Currently, only applicable for the coating of MDF (only a few applications)
Curtain coating	95	Limited by workpiece's geometry
Rolling	95	Limited by workpiece's geometry
Vacumat technique	95	Only applicable for narrow parts and edges, water-based paints and UV curing materials with a high solids content, also the workpiece's geometry has to be considered

<sup>(1)</sup> Depending on the occupancy rate and geometry of the workpieces, etc.  
Source: [13, DFIU and IFARE, 2002]

### 14.2.5 Flashing off and drying/curing

Drying/curing of the paint layer requires an intense flashing-off. The flashing-off takes place in special installations that are generally located upstream of the dryers. For water-based paints, the humidity of the evaporating air needs to be taken into account to enable a sufficient drying.

Some specific drying processes applied (some more commonly applied than others) are:

- through-circulation dryer with dehumidification;
- convection dryers;
- infrared systems:
  - thermal reactors,
  - near infrared drying (NIR drying);
- UV radiation drying;
- microwave;
- high frequency dryers (HF dryers);
- X-ray curing.

### 14.2.6 Examples of some coating processes

#### Coating of chairs

In most of the cases, the first layer used for coating chairs is solvent-based to minimise raising the grain. Chairs made of beech wood are generally coated with a colouring wood stain or a glaze first. After pre-sanding, a first layer of a water-based coat ( $120 \text{ g/m}^2$ ) is applied. The material dries at ambient temperature or via forced drying. After a second sanding, a second layer of water-based paint ( $120 \text{ g/m}^2$ ) is applied and subsequently dried. The electrostatically assisted spray application of water-based paints is usually used for the coating of chairs due to their geometry. Thus the overspray and, therefore, the amount of paint and the VOC emissions are reduced.

### Coating of window frames

Compared with other sectors of the wood industry, the coating of wooden windows is often still carried out manually. As the wood surfaces of windows have to resist weather influences and blue stain infestation, up to four coating layers are partly necessary to achieve sufficient resistance. Both the grinding and the drying processes are very demanding with respect to time and work. The use of water-based paints (e.g. acrylate paints) for the coating of windows is state-of-the-art in Germany, although solvent-based coating systems (e.g. alkyd paints) are also used. Water-based paints show a lower wet adhesion compared to conventional solvent-based paints.

Flooding is a widely used application technique for the coating of pressed frameworks for wood preservation and base coating. Here, the topcoat is applied via spray application in one or two layers in the form of a water-based paint system. Due to the workpiece's geometry, a high amount of overspray is generated even if an electrostatically assisted spraying process is used. To reduce costs and environmental impacts, lacquer recovery installations are utilised. Furthermore, the spraying booths are equipped with a dry separation of overspray in order to avoid coagulation or disposal of paint sludge.

### Coating of high quality furniture

[78, TWG, 2005]

The following process steps are carried out for the coating of high quality furniture:

1. sanding and removal of dust;
2. adaptation of colour, e.g. by staining;
3. sanding and removal of dust;
4. base layer;
5. sanding and removal of dust;
6. top layer.

The second step is mostly by (manual) spraying, steps 4 and 6 also mostly by spraying. UV curing paints are rarely used in the coating of high quality furniture. The main reason is because it can only be applied where flat panels can be coated separately and coating is done before the piece of furniture is assembled. However, if the pieces of the furniture are not yet assembled, it is possible to use UV-based coatings, and hence another type of application than spraying (mostly by rolling).

At least one German company (Rippert GmbH) and one Finnish company (Tikkurila Coatings Oy) have separately developed a UV curing method, which utilises UV curing under inert atmosphere. With this method it is possible to cure UV lacquers and UV paints on 3D components and on assembled chairs. Equipment and coatings are commercially available.

For furniture made of solid pieces of wood (whose surfaces are oiled or waxed) destined for kitchens, bedrooms, living rooms and children's rooms, the following processes are generally carried out:

1. the pre-sanded furniture parts are treated with smoothing brushes;
2. after dedusting, the oil is applied onto the wood surface with a spraying machine;
3. subsequently the oiled workpieces are brushed;
4. a hot wax is applied via spraying;
5. the waxed surface is brushed;
6. the workpieces are turned over and processes 1 to 5 above are repeated.

### Powder coating of MDF panels

Powder application onto MDF panels for the production of television units and office furniture is carried out without previous priming. The entire plant length for preheating, coating, curing

and cooling is significantly shorter than for a conventional plant, as coating takes place in a single working cycle.

Due to the very low electrical conductivity of MDF, the plates are preheated up to 60–70 °C before the powder is applied via corona spray guns. At this temperature, the powder particles adhere to the MDF surface creating a consolidated coating that is subsequently dried by UV radiation. Grinding processes following the respective drying steps are not required.

Due to the recycling and reuse of powder, significant cost savings can be achieved. However, this application technique is only applicable for certain colourings and surface structures.

### **Coating of wooden kitchen and bathroom furniture**

Kitchen and bathroom furniture is made of solid pieces of wood (e.g. oak, beech, maple, stone pine, and cherry) and wood materials (e.g. MDF) and coated. For painting, wet paint systems are used exclusively with a significant proportion of water-dilutable UV paint as well as water- or solvent-based wood stains. At present, solvent-based polyester and PUR paint is only applied in small amounts, partly for the painting of spare parts. Wood stains are applied via automated roller coating heads. Conversion to water-dilutable UV curing paints for base and topcoats was undertaken for environmental, labour protection and technological reasons and in order to reduce the fire hazard. The applied materials have a solvent proportion of 1–2.5 wt-%. The coating is mainly carried out in fully automated installations. The material is applied via compressed air spraying. The overspray is collected (via doctor blades) and reused.

Paint particles of the exhaust air are separated dry. In general, the paint system consists of two layers. The base coat surface can be sanded before the topcoat is applied. Due to the use of water-dilutable UV curing paints, the amounts of emitted solvents are very low and amount, even in big installations, to less than 10 kg/h. Exhaust gas cleaning with regard to VOC is therefore not in use. The exhaust air is emitted directly via a stack. Cleaning agents are recycled via distillation.

## **14.2.7 Finishing with solid coating substances**

Solid coating substances are materials which are pressed in the solid state onto panel-like or profiled workpieces. They may be veneers, sheets, papers or laminates.

### **Veneers**

Veneers are thin sheets of wood having a thickness of about 0.5 to 2 mm and are applied to the base panels by exposing them to temperature and pressure in presses. Standard adhesives are urea-formaldehyde (UF) resins and polyvinyl acetate (PVAC) glues.

### **Sheets, papers or laminates**

These are applied to the base panels using various adhesives by exposing them to temperatures and pressure using surface presses, membrane presses and roller presses. This process is termed lamination. Standard adhesives are glues composed of ethylene vinyl acetate copolymer (EVA) for decorative papers and sheets, and urea-formaldehyde (UF) adhesive resins and polyvinyl acetate (PVAC) glues for laminates.

### **Adhesives and glues**

PVAC glues contain water, the polyvinylacetate binders and organic solvents (generally up to 3 % by mass of butyl or ethyl acetate) and the amounts applied are approximately 120 g/m<sup>2</sup>. During drying, water and not more than 3.6 g of solvent are emitted per m<sup>2</sup>.

UF resins contain urea-formaldehyde resin, possible extenders, catalysts and water. The so-called 'free formaldehyde' component of the adhesive is between 0.1 % and 0.5 % by mass, most of which is incorporated during curing. The amounts applied are approximately 100 g/m<sup>2</sup>. During curing, water and formaldehyde which has not been incorporated are emitted.

EVA glues contain ethylene vinyl acetate copolymer, water and, in some cases, up to 3 % by mass of organic solvents, generally ethanol and toluene. The amounts applied are approximately 90 g/m<sup>2</sup>. During drying, water and, if they are present, up to 2.7 g of organic solvents are emitted per m<sup>2</sup>.

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### 14.3 Current consumption and emission levels in the coating of furniture and wood materials

For the coating of furniture and wood materials the main issue for air pollution control is the emission of VOCs. Wastes and waste water generation, as well as energy consumption are also issues.

#### 14.3.1 Mass balances

No data submitted.

Data were submitted only for two plants in the data collection exercise:

- One installation dedicated to flooring production using water-based coatings (decorative printing / offset technique) in combination with UV sealing varnish (eight coating layers). The water-based coating system is dried thermally. Organic solvents are only used for subsequent cleaning of machinery parts / rollers after production and in the case of colour changes. The overall solvent concentration in the coating materials was less than 1 % while 80 % of the total solvent usage was for cleaning purposes. [155.TWG 2016, #177].
- A second installation producing kitchen fronts operates two coating lines, one using airless spraying with shape air and electric charging (with an efficiency of 20 %) using unsaturated polyester (UP) paints (60 % solid content) and a second roller coating line with an estimated efficiency of 90 % using UV lacquers (99 % solid content).

#### 14.3.2 Consumption

##### 14.3.2.1 Materials

Table 14.6 below itemises the applied quantities of paint materials for different application techniques:

**Table 14.6: Quantities of paint materials applied in different application techniques**

Application technique	Quantity (g/m <sup>2</sup> )	Remarks
Rolling	25–60	
Curtain coating	60–250	In exceptional cases up to 500 g/m <sup>2</sup>
Dipping	60–200	
Flooding	60–200	
Spraying	Up to 250	Material losses due to low efficiency
Printing	1–2	

[13, DFU and IFARE, 2002]

Table 14.7 below gives examples of the amounts of paint and solvent applied on average in each different production sector.



**Table 14.7: Applied paints and amounts of organic solvents: examples of different applications in the wood and furniture industry**

Product	Coating process	Amount of paint (g/m <sup>2</sup> )	Amount of solvent (g/m <sup>2</sup> )
MDF panels	<ol style="list-style-type: none"> <li>base coat, water-based, roller application</li> <li>water-based, roller application</li> <li>printing ink, water-based</li> <li>AC paint via roller application, UV curing*</li> </ol> Drying: convection dryers or UV dryers	80	3
Stairs	<ol style="list-style-type: none"> <li>parquet seal, water-based</li> <li>grinding</li> <li>parquet seal, water-based or solvent-based, spray application of one or two layers</li> <li>hot spraying</li> </ol> Drying: at ambient temperature, convection dryers or infrared drying	180	12
Bedroom furniture	<ol style="list-style-type: none"> <li>spray application of two layers of pigmented water-based or solvent-based paints, with intermediate sanding</li> <li>lime paste, spray application</li> <li>grinding</li> <li>colourless, water-based paints, spray application</li> </ol> Drying: at ambient temperature, tray system dryers	150	9
Doors	<ol style="list-style-type: none"> <li>base coat, water-based, roller application</li> <li>wood stain, roller application</li> <li>AC base coat via roller application, UV curing*</li> <li>grinding</li> <li>two layers of AC paint via roller application, UV curing*</li> </ol> Drying: convection dryers or UV dryers	60	10
Tables	<ol style="list-style-type: none"> <li>combi-stains, spray application</li> <li>AC base coat via roller application, UV curing (3 layers)</li> <li>grinding</li> <li>AC paint via roller application, UV curing</li> </ol> Drying: at ambient temperature	100	30
Living room furniture	<ol style="list-style-type: none"> <li>natural oil, hot spraying</li> </ol> Drying: at ambient temperature	23	0
	<ol style="list-style-type: none"> <li>grinding</li> <li>solvent-based products (for assembled products), UV-based for flat pieces natural wax with hot spraying (infrequent)</li> <li>polishing</li> </ol> Drying: infrared-curing	55	9

\* Solvent-based products are still widely used. In many cases in the furniture industry, UV curing coatings are used, especially for flat pieces, which are nearly all UV cured.  
 Source: [13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

### 14.3.2.2 Water

No data submitted.

### 14.3.2.3 Energy

The main forms of energy input are electricity for the production purposes and natural gas for the needs of the waste gas treatment system. As in the wood machining process there are significant quantities of wood residues remaining (woodchip and wood dust), an interesting option is the use of a dedicated boiler for the exploitation of the energy content of wood residues. The produced heat of the woodchip and dust boiler can be used as heat for the process

(drying ovens) or for the facility needs (room heating). A schematic diagram of this system is shown in Figure 14.1 [155 TWG 2016, # 141].

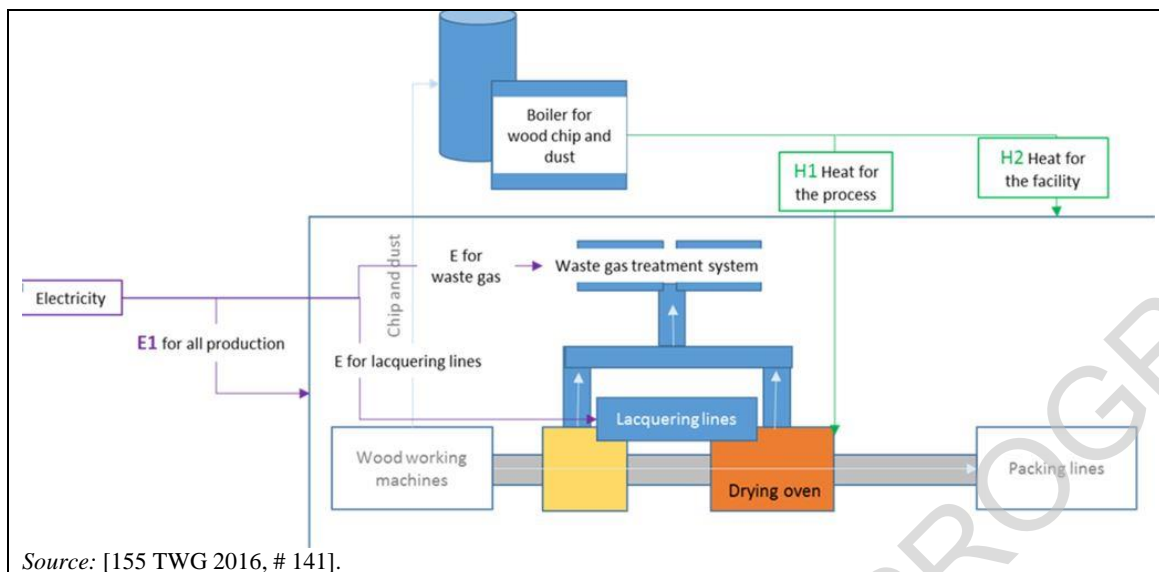


Figure 14.1: Schematic diagram of the energy inputs

No data submitted.

### 14.3.3 Emissions

#### 14.3.3.1 Emissions to air

Table 14.8 summarises some VOC emissions for various painting systems.

Table 14.8: Specific VOC emissions for various paint systems, some with primary emission reduction measures

Application technique	Solvent content (wt-%)	Emission reduction measures	VOC emission (g/m <sup>2</sup> ) *
Paint system with high organic solvent proportion and spraying	65	None	80–100
Paint system with a high organic solvent proportion	65	Application techniques with an increased efficiency factor (rolling, flooding, dipping, electrostatically assisted spraying, airless spraying) and good housekeeping	40–60
Paint system with a medium solvent content	20	Same as above	10–20
Paint system with a low organic solvent content	5	Same as above	2–5

\* These figures depend on the amount of material used and the rate of application. The figures given are for usual rates of application and are a guide only.  
 Source: [13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

Data for emissions to air were only reported from two installations. The first installation (a polyester lacquering line for the coating of kitchen fronts) reported TOC emission values from the exit of two thermal oxidation abatement systems that vary from 4 mg C/Nm<sup>3</sup> up to 11 mg C/Nm<sup>3</sup> (annual monitoring frequency). At the second installation, continuous TOC monitoring of waste gases released from dryers, UV lamps (used for the hardening of coatings) and sanding machines was reported with annual average values that vary from 6.5 mg C/Nm<sup>3</sup> to 9 mg C/Nm<sup>3</sup>.

No concentration values for dust emissions were reported.

### 14.3.3.2 Emissions to water

The volume of generated waste water in the coating of wood is generally very small, since the process water circulates in a closed loop. When using water-based coatings (some of them tested nowadays), a significant amount of waste water is generated, which, in some cases, overflows the closed loop capacity of the spray installation.

### 14.3.3.3 Waste

Especially for the coating of profiled, wooden workpieces, the base and topcoat are applied via spray applications. Thereby, losses via overspray are generated within the spraying booths in one of two waste forms:

- If wet separation is applied, the overspray forms paint sludge. The paint sludge then consists of paint particles, small amounts of organic solvents, coagulation agents and water. Paint sludge is generally regarded as a waste that needs monitoring. In general, the material is used as a fuel in special refuse combustors.
- If the overspray is separated dry, contaminated glass fibre filter mats have to be disposed of. As soon as a specific minimum velocity of the airflow is reached, the filter mats have to be replaced. The filter mats, now contaminated with dried paint particles, generally do not need monitoring and can be used as a fuel in regular waste incineration plants.

Mixed two-component paints cannot be recycled and are disposed of. The solvents are recovered from non-cured paints. In addition, contaminated solvents are generated from the cleaning of application devices, conveyer systems, paint pipelines, spray booths and others. In general, cleaning agents used in the wood industry are recycled via distillation and can be used as recycled cleaning agents. The distillation generates paint leftovers in solid, liquid or paste-like forms. Contaminated solvent, solids from distillation, dried 2K paint and other residues and leftovers that are not reused are disposed of, usually as hazardous waste.

Hazardous properties of paint sludge from paint overspray have been analysed and in many cases, there is a lack of overall background data on wastes. Therefore, co-operation between paint or lacquer producers, waste producers, environmental authorities, and waste researchers and laboratories is very important. For example, in one study in Finland, the formaldehyde concentrations were analysed based on information received from the producers of paints and lacquers. This provided the essential information for overall assessment of the chemical and ecotoxicological hazard of residues studied. The results confirmed the benefit of combining chemical and ecotoxicological assays in assessing the potential environmental hazard of complex organic mixtures found in paint residue wastes. The pretreatment studies showed that the amount of residues could be minimised by reducing the liquid content of water-curtain-booth residues, and the hazard was decreased by changing the raw materials in the spray painting process to paints and lacquers that contain less harmful solvents. The results also proved that landfilling is not a suitable method of disposal for the paint residues produced in the furniture industry. For these types of organic wastes, a better alternative method of treatment could be incineration. The information of the ecotoxicological and leaching properties of excess

paint residues produced in different spray painting processes helped paint producers to develop their products and makes it possible for furniture producers to choose environmentally safer products. Furthermore, this hazard-screening approach will help furniture producers to improve the surface paint process of furniture making in order to minimise the amount and hazard of the wastes produced.

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## 14.4 Techniques to consider in the determination of BAT for the painting of furniture and wood materials

In Chapter 17, techniques are discussed which might also be applicable to the painting of furniture and wood materials. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to the painting of furniture and wood materials. In Table 14.9, the general techniques relevant for the painting of furniture and wood materials that are described in Chapter 17 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

The EGTEI synopsis sheets for the coating of wood (see Annex 21.3.1) give some data on the cost-benefit at a European level of some techniques to reduce VOC emissions. However, the EGTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as cross-media effects or of the technical characteristics of individual installations or products [89, EGTEI, 2005].

**Table 14.9: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### 14.4.1 Minimisation of raw material consumption

#### 14.4.1.1 Batch painting/colour grouping

A general description of the technique is given in Section 17.6.3.1. ~~a general description, see [13, DFIU and IFARE, 2002]~~

##### Example plants

#141, [155, TWG 2016]

#### 14.4.1.2 Pig clearing systems

For a general description, see Section 17.2.4.4. In the furniture industry, there is an increasing demand for furniture to be painted in individual and special colours and, consequently, the use of pig clearing systems.

[13, DFIU and IFARE, 2002]

### 14.4.1.3 Online mixing system for two-component products

For a general description, see Section 17.2.4.1. This technique is commonly applied. [27, VITO, 2003] [13, DFIU and IFARE, 2002]

#### **[Conventional solvent-based materials]**

*This technique has been deleted*

*Conventional techniques have been deleted if they can no longer be considered BAT. This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumption or emissions.*

**Description:** See Section 0. Nitrocellulose paint is classical solvent based furniture paint. However polyester, alkyd, and polyurethane based paints are commonly applied. Alkyd paints are predominantly used as glazes for outdoor applications. Glazes are transparent painting systems being applied to emphasise the appearance of the wood surfaces. However, these glazes can also be water based.

Conventional solvent based paints contain the following solvent contents by weight:

- wood stain: 95 % organic solvent
- wood stain: 70 % organic solvent, 30 % water
- base coat and topcoat: up to 80 % organic solvent.

**Achieved environmental benefits:** Compared to water based systems, less energy is required for drying.

**Cross-media effects:** High VOC emissions.

**Operational data:** Solvent based paints have a shorter drying time and, thus, a higher production capacity can be achieved.

**Applicability:** No data submitted.

**Economics:** No data submitted.

**Driving forces for implementation:** Short drying times are an important issue in the use of solvent technology.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002] [78, TWG, 2005]

## 14.4.2 Replacement of solvent-based materials (substitution)

### 14.4.2.1 Water-based coatings

#### **Description**

For the general description, see Section 17.7.2.2. The following water-based coating systems are applied:

- wood stain: 0 % organic solvent;
- wood stain: 25–30 % organic solvent
- base and topcoat: 5–7 % organic solvent; conventional drying system.

Water-based UV curing paints (about 2 % organic solvent) and two-component paints based on polyurethane (about 9 % organic solvent) are also applied.

**Achieved environmental benefits**

Significant VOC reductions.

**Cross-media effects**

Extra sanding and polishing is often necessary to get a smooth surface after each painting step. This produces more waste and more raw materials are consumed.

**Operational data**

No data submitted.

**Applicability**

Two-component paints are widely applied in painting, e.g. for durable surfaces such as floor coverings and kitchen fronts.

The application of water-based paints depend on the product used, the surface, the base coat layer (primer), the application method, the desired 'end quality', the availability of high quality products and the product segment the company is aiming at. Currently, the availability of high quality coatings is not sufficient.

**Economics**

The following investments may be necessary:

- forced drying (usually the largest investment);
- additional area needed for the dryer as well as the larger intermediate storage for painted workpieces, in between repeated operation cycles;
- stainless steel equipment for paints storage, tools manipulation equipment, etc. whereas standard steel grades can be used for solvent-based paints.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [27, VITO, 2003] [96, Presti, 2005]

**14.4.2.2 Powder coating – conventionally dried****Description**

See Section 17.7.2.8. Powder coatings with conventional convection drying are applied to MDF and HDF (medium and high density fibres). They are currently not suitable for the painting of wood, because of the high temperatures needed for drying and the low surface quality achieved.

**Achieved environmental benefits**

No data submitted.

**Cross-media effect**

No data submitted.

**Operational data**

The powder application onto MDF panels for the production of television and office furniture is carried out without previous priming. The entire length of plant needed for preheating, coating, curing and cooling is significantly shorter than that needed for a conventional plant: coating

takes place in a single working cycle. Sanding processes following the respective drying steps are inapplicable.

Due to the very low electrical conductivity of MDF, the plates are preheated up to 60–70 °C before the powder is applied via electrostatically assisted spray guns. At this temperature, the powder particles adhere to the MDF surface creating a paint layer which is consolidated and subsequently dried by UV radiation.

Low temperature powder coatings, suitable for wooden substrates in general, are applied in, e.g. Sweden and the UK. This technique is not commonly applied.

The reuse of overspray is not possible in short production runs and for frequent colour changes, which often occurs in furniture manufacturing.

### **Applicability**

Only used for MDF, and for low quality parts. Not suitable for coating solid wood or veneers.

### **Economics**

Due to the recycling and reuse of powder, significant cost savings can be achieved.

### **Driving force for implementation**

No data submitted.

### **Example plants**

Stilexo Industrial, UK.

### **Reference literature**

[13, DFIU and IFARE, 2002] [78, TWG, 2005] [27, VITO, 2003]

## **14.4.2.3 UV radiation curing paints**

### **Description**

See Section 17.7.2.4.

### **Achieved environmental benefits**

Water-based and solvent-free radiation curing paints do not generate VOC emissions.

### **Cross-media effects**

None.

### **Operational data**

UV curing paints can be applied by several different techniques, such as brushing, rolling, casting, spraying and vacuum coating.

### **Applicability**

UV curing water-based coatings are not currently commonly used, but are increasingly applied in furniture and wood painting. UV curing water-based paints are commonly applied in the coating of chairs, boxlike furniture, office and kitchen furniture, room doors, panels, chipboard for living and bedroom furniture, etc. These paints can be applied for all paint layers. UV curing products are possible where flat panels can be coated separately and coating is done before assembling the piece of furniture. There can be some application of UV curing coatings in the section of joinery and finishing panels. The use of infrared curing products is less known.

At least one German company and one Finnish company have separately developed a UV curing method, which utilises UV curing under inert atmosphere. With this method, it is possible to cure UV lacquers and UV paints on 3D components such as assembled chairs. Equipment and coatings are commercially available.



**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

#144, for 3D coatings: Rippert GmbH, Germany, Tikkurila Coatings Oy, Finland.

**Reference literature**

[13, DFIU and IFARE, 2002], [38, TWG, 2004] [78, TWG, 2005] [155, TWG, 2016]  
For coating in 3D: RadTech 2005 conference proceedings, [www.tikkurila.fi](http://www.tikkurila.fi).

**14.4.3 Paint application techniques and equipment****14.4.3.1 Rolling and filling by using reverse coaters****Description**

See Section 17.7.3.1. Filling is commonly applied.

**Achieved environmental benefits**

The efficiency of this is very high. Depending on the workpiece and the processing conditions, material efficiencies of about 90–100 % can be achieved. Material savings of up to 40 % can also be achieved.

**Cross-media effects**

No data submitted.

**Operational data**

In most cases, normal roller coating is used, with good results, including on closed-cell surfaces.

In 2002, an increasing demand was seen for coatings for closed-cell substrates such as beech, maple, pear, birch, and cherry woods. For the best quality veneer, this had previously only been possible with conventional rolling or spray applications. However, the use of heated smoothing rollers for the application of base coat shows significant advantages. It enables the filling and smoothing of porous surfaces without the application of excess material. Furthermore, cracks in the surface of the veneer and joint connections, raw chipboards, MDF panels and other wood material panels can be filled. Thus, a smoother surface is created and the wood gets a filled and smooth appearance.

These advantages are caused by the opposite rotating heated smoothing rollers that process the UV paint applied onto the workpiece surfaces via the application roller. In this way, the paint is worked into the workpiece's surface. Pores, veneer cracks and splices are also filled this way. The heating of the smoothing roller ensures that the cohesion within the paint layer is reduced, so that the material remains in the filled pores. Additionally, the paint material shows better running properties and forms a plain, even surface.

**Applicability**

In general, rolling techniques are in use for the application of water-dilutable paints and UV radiation curing paints. Mainly applicable to flat workpieces, but also slightly curved products such as wooden panels can be processed. Application weights from 25–60 g/m<sup>2</sup> can be processed, according to the machine type. Reverse coaters are only applicable for flat workpieces and, therefore, mainly used for plates derived from wood products. For more curved surfaces, stoppers are applied by hand operated equipment such as palette knives.

### **Economics**

A lightweight filling machine used in wood and furniture coating, with a working width of 1.3 metres and an installed electrical load of 5.5 kW cost EUR 55 000 in 2000. A machine used in wood and furniture coating with, for example, a foam roller, a working width of 1.3 metres and an electrical load of 3 kW costs about EUR 30000. A machine applying two rollers (double system) with the same working width and an electrical load of 6 kW costs EUR 60000. Both examples are from 2005.

### **Driving force for implementation**

No data submitted.

### **Example plants**

#141 No data submitted.

### **Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005] [155, TWG 2016]

## **14.4.3.2 Curtain coating (casting)**

### **Description**

See Section 17.7.3.5. Curtain coating (casting) is commonly applied for coating doors, wall units and other plates. Mostly solvent-free lacquers based on polyester are applied, but also other types of coating materials can be processed. Curtain coating can achieve a high quality in the equality of layers.

### **Achieved environmental benefits**

Depending on the workpiece and the conditions of processing, material efficiencies of about 90–98 % can be achieved.

### **Cross-media effects**

No data submitted.

### **Operational data**

In comparison to rolling, the wooden workpieces do not have to be absolutely plain. Within a curtain coater, the paint material used is pumped into a header tank from where the coating is discharged in the form of a fine lamina film. The workpieces that need to be coated are sent through this film. Excess paint material is collected in a reservoir and pumped back into the header tank. An efficiency of approximately 95 % is achieved. All types of paint materials can be applied by this technique.

### **Applicability**

In the casting process, plain or almost plain workpieces are coated. According to the machine type, application weights from 60–250 g/m<sup>2</sup> can be processed.

### **Economics**

A casting installation applied in wood and furniture coating with a working width of 1.3 metres and an installed electrical load of 3 kW costs EUR 35 000 (year 2000).

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

### **Reference literature**

[13, DFIU and IFARE, 2002] [27, VITO, 2003] [78, TWG, 2005]

### 14.4.3.3 Conventional Dipping

*Proposed for deletion*

#### Description

See Section . The conventional dipping technique is commonly applied for the coating of windows in serial production.

#### Achieved environmental benefits

The advantages of dipping is that it produces very high efficiencies of up to 100 %, complete coatings of workpieces (of outer surfaces as well as inner), cost effectiveness, high operational capacity and good possibilities for automation. However, efficiency ranges of 80–90 % are also reported.

#### Cross-media effects

Compared to spraying, thicker coating layers are achieved which might consequently result in a higher consumption of raw material.

#### Operational data

Workpieces are either dipped manually or transported and dipped via conveyor systems. Dipping into water-based paints might produce foam. Water-based paints are only stable in a small range of pH levels and, therefore, very sensitive to contaminations that might be dragged over from the pretreatment processes. A drying step after pretreatment, such as cleaning processes, is often not necessary when applying water-based paints. The dipping tank must be equipped with a mixer, circulation pump with filter and thermoregulator.

Application weights from 60–200 g/m<sup>2</sup> can be processed.

#### Applicability

For the serial production of bulk articles that are coated in a single tone without colour changes, dipping is applicable. Only one-component paint systems are applicable.

This technique is not applicable for open-cell surface structures of coated products. Also mostly, parts of furniture that are treated differently (e.g. fronts, inlays, backsides) and profiles cannot be dip coated (pore formation is not possible) due to the unfavourable overstretching of profiles.

#### Economics

This is a cost-effective technique.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

[13, DFIU and IFARE, 2002] [27, VITO, 2003] [96, Presti, 2005]

### 14.4.3.4 Flooding

#### Description

See Section 17.7.3.6.

#### Achieved environmental benefits

Depending on the workpiece and the conditions of processing, efficiencies of 95–99 % can be achieved. In comparison to the dipping application, the evaporation losses are higher.

### **Cross-media effects**

No data submitted.

### **Operational data**

In flood coating installations, the workpieces are transported via conveyor systems into closed channels. There, the workpieces are flooded with the paint material via injection tubes. The surplus paint material is absorbed at the bottom of the channel and reused.

Application weights from 60–200 g/m<sup>2</sup> can be processed.

### **Applicability**

The process is especially suitable for wooden workpieces that tend to swim. Applicable for serial production and large workpieces with a large surface area, without a lot of colour changes.

### **Economics**

No data submitted.

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

### **Reference literature**

[13, DFIU and IFARE, 2002],

## **14.4.3.5 Vacuum coating**

### **Description**

See Section 17.7.3.7.

### **Achieved environmental benefits**

Depending on the workpiece and the conditions of processing, efficiencies of 80–100 % can be achieved.

### **Cross-media effects**

None.

### **Operational data**

Vacuum coating is only applicable to wood that can withstand vacuum. To test this, a piece of wood is put under low pressure (i.e.  $< 10^{-6}$  bar). The wood is not suitable for vacuum coating when the pressure rises with some  $10^{-6}$  bar per minute.

Apart from water-based paints, vacuum coating has also been recently applied to UV curing paint on wood or wood-composites.

### **Applicability**

Vacuum coating is commonly applied in the painting of MDF panels, solid wood, veneer, profiles made out of paper composites, window panes, skirting boards, and panels for walls and ceilings.

### **Economics**

In a real case situation, changing from air-assisted airless spraying of water-based paints with infrared drying to vacuum coating, applying UV curing paints resulted in a yearly saving of EUR 262 000. The machine cost was EUR 140 000. Payback time was less than two years. The

result was avoidance of VOC emissions (14 tonnes/yr) and waste (which used to be 100 tonnes/yr) and the material of the UV curing paint was 100 % efficient (2003).

**Driving force for implementation**

No data submitted.

**Example plants**

True Temper Hardware Company, Pennsylvania, US, producing wooden stems and handles.

**Reference literature**

[27, VITO, 2003], [38, TWG, 2004]

**14.4.3.6 Conventional high- and low-pressure spraying**

*Proposed for deletion*

**Description**

See Section . Compressed air spraying is used, for example for the application of water-based UV curing paint (1–2.5 wt-% organic solvent) in an automated installation for the coating of kitchen and bathroom furniture.

**Achieved environmental benefits**

No data submitted.

**Cross-media effects**

Raw material consumption is very high (see application efficiencies in Operational data, below).

**Operational data**

All surfaces can be coated by this method and high surface qualities can be achieved.

**Applicability**

The efficiency varies from about 5 % for lattice-like workpieces to about 30–60 % for workpieces with a larger surface area.

**Economics**

No data submitted.

**Driving force for implementation**

Widely used. Represents the status quo.

**Example plants**

Widely used.

**Reference literature**

[13, DFIU and IFARE, 2002]

**14.4.3.7 High-volume low-pressure spraying (HVLP)**

See Section 17.7.3.12. This is commonly applied for low viscous wood stains and increasingly for other paint systems. [13, DFIU and IFARE, 2002]

#### **14.4.3.8 Electrostatically assisted compressed air, airless and air-assisted spraying**

##### **Description**

In this technique, the paint is atomised in an electric field, see Section 17.7.3.14. Electrostatically assisted spray applications can be utilised if more electrically conductive materials, such as solid wood for the production of windows, chairs and pad racks are processed.

##### **Achieved environmental benefits**

No data submitted.

##### **Cross-media effects**

No data submitted.

##### **Operational data**

No data submitted.

##### **Applicability**

The Faraday cage effect makes it impossible for the paint particles to reach cavities. The humidity of wood needs to be at least 10 % to achieve sufficient conductivity of the workpiece.

##### **Economics**

No data submitted.

##### **Driving force for implementation**

No data submitted.

##### **Example plants**

No data submitted.

##### **Reference literature**

[13, DFIU and IFARE, 2002] [96, Presti, 2005]

#### **14.4.3.9 Powder coatings – electrostatically assisted spraying**

##### **Description**

See Section 17.7.3.14. Powder coatings can be applied by all common spray application techniques. However, the best results are achieved via electrostatically assisted spraying.

##### **Achieved environmental benefits**

No data submitted.

##### **Cross-media effects**

No data submitted.

##### **Operational data**

Due to the very low electrical conductivity of MDF, the plates are preheated up to 60–70 °C before the powder is applied by electrostatically assisted spraying. At this temperature, the powder particles adhere to the MDF surface creating a paint layer which is consolidated and subsequently dried by UV radiation.

##### **Applicability**

Commonly applied when powder coating is used for the painting of furniture and wood.

##### **Economics**

No data submitted.

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

No data submitted.

#### **Reference literature**

[13, DFIU and IFARE, 2002]

### **14.4.4 Spray booths**

#### **14.4.4.1 Wet separation booth**

##### **Description**

See Section 17.10.4.1. This is a spray booth of stainless steel equipped with a water spray at the back and possibly sides, to absorb the overspray. These are commonly applied and equipped with cascades, or the water is circulated with air flotation and with paint recycling.

##### **Achieved environmental benefits**

No data submitted.

##### **Cross-media effects**

No data submitted.

##### **Operational data**

No data submitted.

##### **Applicability**

No data submitted.

##### **Economics**

Purchasing costs for a wet separation spray booth with a capacity of 13 kW and 7 000 m<sup>3</sup>/h air output is EUR 150 000 (reported 2002).

##### **Driving force for implementation**

No data submitted.

##### **Example plants**

No data submitted.

##### **Reference literature**

[13, DFIU and IFARE, 2002] [27, VITO, 2003]

#### **[Paint-in-paint spray booth]**

*[This technique has been deleted]*

**Description:** See Section 0.

**Achieved environmental benefits:** Typically 33–50 % of the overspray can be re-used.

**Cross-media effects:** None.

**Operational data:** Different designs are available, also as an integrated part of an automated spraying zone or line. Cleaning the screen after a colour change takes about five minutes.

**Applicability:** This process is applicable for 1 component, solvent and water based paints. It can be applied in automated and manual spraying activities. It is, however, less suitable for small series with many colour changes and for paints with a short shelf life. Mostly dry or wet spray booths are used. The many different colours used makes this application sometimes impossible to apply.

**Economics:** The price level of these spray booths is between EUR 25000—60000 for air output flows of 5000—10000 m<sup>3</sup>/h. Purchasing costs for a spray booth for manual spraying with a capacity of 15 kW and 7200 m<sup>3</sup>/h air output is EUR 80000.

The investment costs for a ‘water curtain wall’ in a traditional manual spray cabin are between EUR 30000 and 75000 depending on the size of the wall. The investment cost for a rotating system is between EUR 40000 and 180000 for one spray cabin (reported in 2006).

Energy costs for the cooling of the screen are about EUR 1000 per year. Savings include a reduction of raw material because paint is re-used and less waste paint needs to be disposed of.

The system is economically viable for companies applying 15 tonnes of paint or more per year. Reported payback times of six case studies are in the range 1.5—5 years.

**Driving forces for implementation:** No data submitted.

**Example plants:** Airtech from Denmark.

**Reference literature:** [13, DFIU and IFARE, 2002], [27, VITO, 2003], [38, TWG, 2004] [95, CEI BOIS, 2006]

### 14.4.5 Drying

#### 14.4.5.1 Convection drying

*Proposed for deletion*

For a general description see Section. This is commonly applied in wood and furniture coating. The drying of wood or synthetics is limited.

[13, DFIU and IFARE, 2002] [27, VITO, 2003]

#### 14.4.5.2 Microwave dryer

##### Description

For a general description, see Section 17.8.3.

##### Achieved environmental benefits

No data submitted.

##### Cross-media effects

No data submitted.

##### Operational data

It has been reported by a national industry association that there are not many examples of water-based coatings in the furniture industry being used.

##### Applicability

A microwave dryer is not suitable for thick workpieces (> 20 cm). This technique is not commonly used in Europe.

##### Economics



The costs for an installation (without the connection, etc.) are between EUR 55 000–100 000 (12 kW).

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

One experimental installation in Norway. The energy consumption is estimated to be 10–30 % higher versus traditional techniques (IR, hot air).

#### **Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [95, CEI-BOIS, 2006] [96, Presti, 2005]

#### **14.4.5.3 High-frequency dryers**

For a general description, see Section 17.8.3. Due to the fast evaporation of water, the napping of wood fibres and the amount of dust arising is significantly reduced. It has been reported by a national industry association that there are not many examples of water-based products in the furniture industry being used. Finishing panels is done with UV curing products, which requires other types of dryers.

[13, DFIU and IFARE, 2002] [38, TWG, 2004]

#### **14.4.5.4 Infrared radiation curing**

For a general description, see Section 17.8.3.1. This technique is applied in combination with circulating air dryers. Infrared radiation may alter the wood.

[13, DFIU and IFARE, 2002] [38, TWG, 2004]

#### **14.4.5.5 Near-infrared radiation curing**

For a general description, see Section 17.8.5.1. This technique is commonly applied because it is very suitable for heat sensitive materials such as wood due to very short (1–5 seconds) curing times. Powder coatings are usually cured by applying NIR curing as also water-based paints on wood. Regarding the coating of wood, the NIR technique achieves the shortest drying and cycle times.

[13, DFIU and IFARE, 2002]

#### **14.4.5.6 Ultraviolet (UV) radiation**

For a general description, see Section 17.8.5.2. This technique is widely applied for the drying of painted furniture, especially of flat parts. Wooden or plastic substrates can show a yellowing and may become brittle. A technique also commercially exists to cure UV coatings in 3D, see Section 14.4.2.3.

[13, DFIU and IFARE, 2002] [27, VITO, 2003]

#### **14.4.5.7 Electron beam curing**

For a general description, see Section 17.8.5.3. This technique requires a special and solvent-free coating substance. Due to high investment costs, this technique is currently only applied for large surface throughputs.

[13, DFIU and IFARE, 2002] [57, VDI, 2005]

#### **14.4.5.8 Combined convection/radiation drying (thermal reactor)**

For a general description, see Section 17.8.4 . The technique is applied in the coating of wood. The coated substrate should be heat resistant.  
[13, DFIU and IFARE, 2002] [38, TWG, 2004]

#### **14.4.6 Waste gas treatment**

##### **14.4.6.1 Dry particle filter systems**

For a general description, see Sections 17.10.4.4 & 0. Paint stop filters and paper filters are commonly used in the wood and furniture industry. Particulate emission values of 10 mg/m<sup>3</sup> or less are achieved using this technique. At this level, filters may require replacement and are discarded as waste at least every other day, with associated costs and cost-media impacts.  
[27, VITO, 2003] [137, CEI-BOIS, 2006]

##### **14.4.6.2 Electrostatic filter**

For a general description, see Section 17.10.4.6. Spray booths are applied. However, no information was made available on how the waste water and waste gas is treated. This technique is sometimes considered as not economical for the sector.  
[13, DFIU and IFARE, 2002] [38, TWG, 2004]

##### **14.4.6.3 Venturi particle separation**

For a general description, see Section 17.10.4.3. Wet separation spray booths are applied. However, no information was made available on how the waste water and waste gas is treated. This technique is sometimes considered as not economical for the sector.  
[13, DFIU and IFARE, 2002] [38, TWG, 2004]

##### **14.4.6.4 Scrubber**

For a general description, see Section 17.10.4.2. Wet separation spray booths are applied. However, no information was made available on how the waste water and waste gas is treated. Particulate emission values of 10 mg/m<sup>3</sup> or less are achieved, although this technique is sometimes considered as not economical for the sector.  
[27, VITO, 2003] [13, DFIU and IFARE, 2002] [38, TWG, 2004] [137, CEI-BOIS, 2006]

##### **14.4.6.5 Biological treatment**

For a general description see Section 17.10.7. In Germany, only one plant is equipped with a biofiltration system for the reduction of odour.  
[13, DFIU and IFARE, 2002]

##### **14.4.6.6 Thermal oxidation**

For a general description, see Section 17.10.5.2. Although theoretically applicable, this is currently not applied.

This technique may be considered as not economically viable when VOC concentrations are low and/or the gas flows are high, because of the high investment and operational costs (additional heat input, electricity consumption of fans). Many wood-based companies work discontinuously and in single or double shift operations. This makes steady conditions hard to realise, as the thermal inertia after cooling down reduces thermal efficiency, and some installations have complex process control equipment that needs time to stabilise after start-up or adjustment. Moreover, VOC loads in exhaust gas flows might be quite irregular during a shift.

However, it may be considered where there is no alternative to using high solvent coatings. Simple thermal oxidation is well-suited to intermittent use and flows < 2 000 m<sup>3</sup>/h, although varying VOC loads may be a problem (see Annex 21.9).

[13, DFIU and IFARE, 2002] [96, Presti, 2005]

#### **14.4.6.7 UV oxidation**

*ESVOC propose deletion TWG please confirm*

For a general description, see Section . Reported data are applicable to wood and furniture painting when applying solvent-based paints. However, the technique is currently not applied in this sector. It is also not applicable when veneer is coated. This technique is sometimes considered as not economical for the sector.

[14, Aminal, et al., 2002] [13, DFIU and IFARE, 2002] [24, ESIG, 2000] [27, VITO, 2003] [38, TWG, 2004]

#### **14.4.7 Waste water treatment**

##### **14.4.7.1 Waste water treatment for wet separation paint spray booths**

See Section 17.10.4.1; and Section 17.11 describes treatment options.

##### **14.4.7.2 Ultra and nanofiltration**

For a general description, see Section 17.11.8. Wet separation spray booths are applied and are equipped with an ultrafiltration unit to separate and recover the paint material. This technique is sometimes considered as not economical for the sector.

[13, DFIU and IFARE, 2002] [38, TWG, 2004]

#### **14.4.8 Waste treatment**

##### **14.4.8.1 Recovery of used solvents by applying distillation**

For a general description, see Sections 0 and 17.12.3.2. Recovery of cleaning agents is commonly applied, e.g. in the coating of wooden kitchen and bathroom furniture.

[4, Intergraf and EGF, 1999] [13, DFIU and IFARE, 2002] [26, CITEPA, 2003] [68, ACEA, 2004]

WORKING DRAFT IN PROGRESS

## 15 WOOD PRESERVATION

[108, DFIU/IFARE, 1999] [109, European Environmental Agency, 2001] [128, TWG, 2005] [140, EGTEL, 2005]

### 15.1 General information on wood preservation

This section considers the industrial processes for the preservation with, or immersion of wood in organic solvent based preservatives, creosote or solvent free preservatives. Wood is preserved to protect it against fungal and insect attack and also against weathering of wood and wood products with chemicals.

Many wood species possess insufficient or no natural resistance to wood-destroying or wood-staining organisms for the specific end uses. Where the natural protective constituents are insufficient or totally absent, wood and wood products are treated with preservatives to protect them from the damaging effects of fungi, bacteria, insects, water, weather or fire; providing long-term conservation of structural integrity and improving the resistance.

Wood or wood products treated with wood preservatives can be found, for example, in the building and construction sector (wood lattices, bridges, alpine cabins or chalets, etc.), in gardening and landscaping (fences, arches, etc.), as well as in agriculture (poles for fruit and wine growing), toys and playground equipment, avalanche and noise barriers, railway sleepers and telegraph poles. Depending on where the wood is used, use classes in a range of 0–5 are defined. The higher the number of the use class, the more the wood needs to be protected from wood-destroying organisms.

Wood preservation can take place in specialised companies, as a part of the production in sawmills (where sawmills offer not only sawn timber, but also treated timber) or in other wood processing industries, e.g. window and door production.

Wood preservation is a major industry, with 11.5 million m<sup>3</sup> of wood treated yearly in the EU alone. The sector is characterised by a large number of relatively small plants. It has been estimated that 1 000 installations are involved in the treatment of wood in the EU-15. It is reported that 68 % of the plants use less than 25 t/yr of solvents. [STS BREF 2007]

Accurate figures on the size distribution, production, employment or trade balance of the sector in the EU are lacking. The results of a data gathering exercise conducted in preparation for a potential review of the IPPC Directive ('Data gathering and impact assessment for a possible technical review of the IPPC Directive – Part 2', Fact sheet B5 Wood preservation, September 2007) are given in Table 15.1 below.

**Table 15.1: Results from a questionnaire concerning the number and size of installations for the preservation of wood**

Country	Total number	< 50 m <sup>3</sup> /day	50–100 m <sup>3</sup> /day	> 100 m <sup>3</sup> /day
Austria	3 <sup>(1)</sup>	NI	NI	NI
Czech Republic	55	53	1	1
Hungary	7	NI	NI	NI
Latvia	17	12	2	3
<b>Total</b>		65	3	4

(1) Installations for wood preservation exceeding a consumption of 25 tonnes organic solvent per year.  
 NI: no information provided  
 Source: [Fact sheet B5 2007]

From a questionnaire that was sent to 10 international suppliers of wood preservation agents, only 1 response (supplier of creosote) was returned. The result is given in Table 15.2, however this provides only a very incomplete picture. The information only refers to installations using creosote in some western European Member States. Of these installations, 60 % treat less than 50 m<sup>3</sup>/day. No additional information was obtained from the installations using waterborne products or light organic solvent preservation products or on the situation in other parts of Europe.

**Table 15.2: Estimate of number and size of installations for wood preservation in the EU from one supplier of creosote**

Country	Total number	< 50 m <sup>3</sup> /day	50–100 m <sup>3</sup> /day	> 100 m <sup>3</sup> /day
<b>Austria</b>	1	NI	NI	1
<b>Belgium</b>	2	1	1	NI
<b>France</b>	1		1	NI
<b>Germany</b>	7	6	1	NI
<b>Ireland</b>	1	NI	NI	1
<b>Netherlands</b>	1	1	NI	NI
<b>UK</b>	4	3	NI	1
<b>Total</b>		11	3	3

NI: no information provided  
Source: [Fact sheet B5 2007]

From analysis of reports on the implementation of the SED submitted by the Member States, the following (incomplete) table was derived. This represents only those installations that impregnate wood with a solvent consumption of 25 t per year or more.

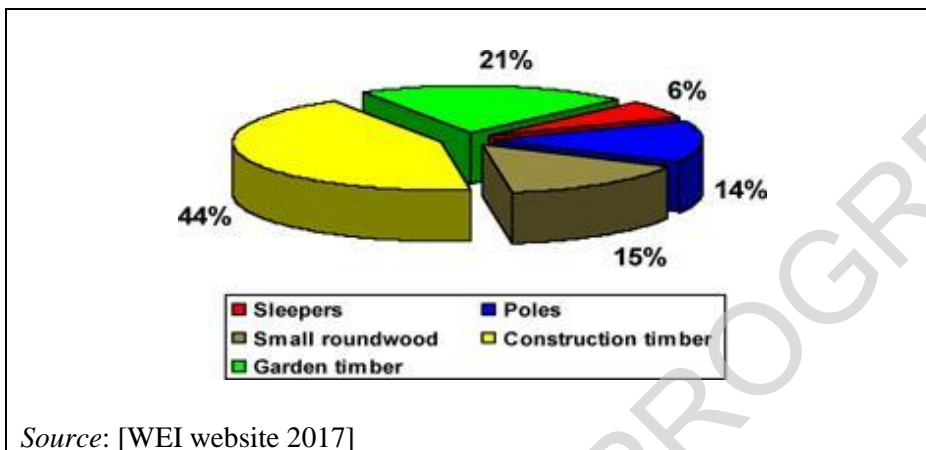
**Table 15.3: Existing installations for wood impregnation encompassed by Article 2(2) of the SED, 2003–2004**

Country	Number of installations
Austria	3
Belgium	1
Denmark	3
Finland	0
France	648
Germany	10
Greece	4
Ireland	72
Italy	NI
Luxembourg	0
Netherlands	0
Portugal	0
Spain	4
Sweden	NI
UK	17
<b>Total</b>	<b>762</b>

NI: no information provided

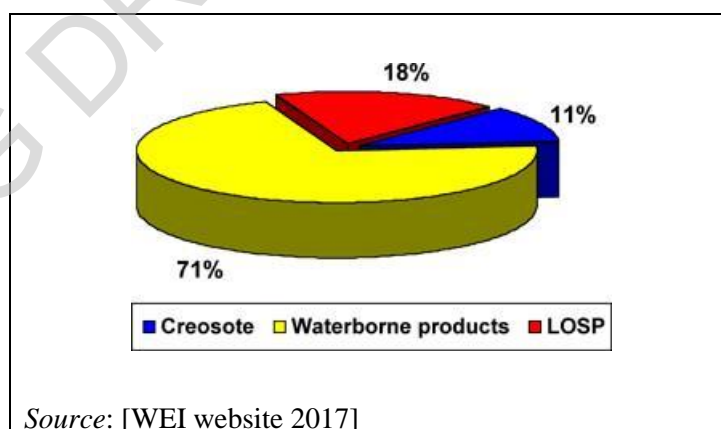
**Pressure-treated wood** [WEI website 2017]

Europe's wood preservation industry supplies around 6.5 million m<sup>3</sup> of pressure-treated wood per year for woodworking, construction, landscaping, leisure wood, agriculture, marine, railway, telecommunication, electricity generation and distribution applications. As shown in Figure 15.1, 44 % of the production (of pressure-treated wood) is used as garden timber, 21 % as construction timber, 15 % as small roundwood and 6 % as sleepers.



**Figure 15.1: European wood preservation industry production categorised by types of product**

In total, 71 % of the wood is treated with water-based preservatives, 11 % with creosote, mainly poles and sleepers, and 18 % with solvent-based preservatives, mainly construction timber such as window and door joinery (see Figure 15.2). Creosote impregnation is generally declining because regulations have become tighter and because of new non-wooden products, e.g. the use of concrete sleepers for new railway lines. In the case of poles, however, an increased use of creosote in impregnation has been reported in Europe. A significant share of this is exported to countries outside the EU. [WEI website 2017]



**Figure 15.2: European wood preservation industry production categorised by preservative type**

Only limited information was submitted on the total number of plants and the number of IED plants in the EU. The data submitted often lack information on the preservative type used (WB, SB or creosote) and/or refer to estimates. Only a few Member States (MS) submitted information (statistics) on their wood preservation industry. [WEI website 2017]

Table 15.4 provides an overview of the information available on the wood preservation industry in the EU Member States

Table 15.4: Number of WPC plants (total) and of WPC plants > 75 m<sup>3</sup> production capacity per preservative type reported by EU Member States (status 5/2017)*(TWG members are asked to complete and/or update the information.)*

Member State	Water-based preservatives	Solvent-based preservatives	Creosote	Mixed WB-C	Mixed SB-C	Mixed WB-S	
	∑ WPC plants/ IED plants <sup>(1)</sup>	∑ WB plants/ IED plants	∑ SB plants/ IED plants	∑ C plants/ IED plants	∑ WB-C plants/ IED plants	∑ SB-C plants/ IED plants	∑ WB-S plants/ IED plants
Austria	NI / 0	NI / 0	NI / 0	NI / 0	NI	NI	NI
Belgium <sup>(2)</sup>	9 / 8	4 / 3	1 / 1	1 / 1	1 / 1	2 / 1	NI
Bulgaria	NI	NI	NI	NI	NI	NI	NI
Croatia	NI	NI	NI	NI	NI	NI	NI
Cyprus	NI	NI	NI	NI	NI	NI	NI
Czech Republic	NI	NI	NI	NI	NI	NI	NI
Denmark	NI / 2	NI / 2	0	0	NI	NI	NI
Estonia	NI	NI	NI	NI	NI	NI	NI
Finland	21 / 7 – 11*	18 / 4–8	NI	1 / 1	2 / 2	NI	NI
France	NI / identified 36 (60–100*)	NI / 30* (others)	NI / 30* (others)	NI / 6*	NI	NI	NI
Germany	NI / 0–25*	60–120 / 0–25	0	7 / 0	NI	NI	NI
Greece	NI	NI	NI	NI / 1	NI	NI	NI
Hungary	NI	NI	NI	NI	NI	NI	NI
Ireland	20 / 8	NI	1 / 1	NI	NI	1 / 1	NI
Italy	NI	NI	NI	NI	NI	NI	NI
Latvia	NI	NI	NI	NI	NI	NI	NI
Lithuania	NI	NI	NI	NI	NI	NI	NI
Luxembourg	NI	NI	NI	NI	NI	NI	NI
Malta	NI	NI	NI	NI	NI	NI	NI
Netherlands	2 / NI	NI	0	2 / NI	NI	NI	NI
Poland	NI	NI	NI	/	NI	NI	NI
Portugal	NI	NI	NI	NI	NI	NI	NI
Romania	NI	NI	NI	NI	NI	NI	NI
Slovakia	NI	NI	NI	NI	NI	NI	NI
Slovenia	NI	NI	NI	NI	NI	NI	NI
Spain	NI	68 / 0	78 / 0	3 / 0	NI	NI	NI
Sweden	NI	NI / 15	NI / 1	NI	NI / 2	NI	NI / 1
United Kingdom	NI	NI / 160*	NI / 35*	NI / 5*	NI	NI	NI

<sup>(1)</sup> IED plants refers to plants exceeding the threshold of IED Annex I, 6.10 , i.e. plants with a production capacity of > 75 m<sup>3</sup> wood per day. (No information was submitted on WPC plants being IED plants due to exceeding the relevant thresholds of IED Annex I, 6.7 (solvent consumption capacity of > 150 kg/h or 200 t/y).)

<sup>(2)</sup> One IED plant (> 75 m<sup>3</sup>) reported with unknown preservative type.

NI = no information provided.

\* Estimate.



**Environmental impacts**

The environmental issues related to the preservation of wood with chemicals are strongly linked to the chemicals that are used to impregnate the wood. The preservatives used are basically: water-based, tar-oil-based (creosote) or solvent-based preservatives. Impregnation of wood potentially causes emissions to air, releases of hazardous substances to water, and risks of soil/groundwater contamination. In addition, energy aspects and waste generation are issues to consider.

***Emissions to air***

The main emission to air is caused by the solvent content of the solvent-based and creosote preservatives (volatile organic compounds (VOCs)). Aerosols and vapours may be emitted during loading, storage, handling, mixing processes involving organic solvents and organic-solvent-containing materials, as well as during preservative solution handling.

A major source of aerosol emissions from the (pressure) preservation process may be when the vessel door is opened after the treatment cycle. During treatment, additional vapour emissions may occur from the treatment tank during the initial vacuum stage, the flooding under vacuum, pressure relief and blowback, and the final vacuum. Aerosols and vapour may also be emitted from the vessel door area when opening. The majority of the diffuse emissions occur during the drying stages, as the wood treated with solvent-based agents or creosote still emits VOCs to air for some time.

Cleaning operations using organic-solvent-borne cleaning fluids and handling and storage of waste organic solvents and organic-solvent-contaminated wastes can also give rise to VOC emissions.

Due to the composition of the preservative, PAH (including benzo(a)pyrene) emissions to air and odour are issues for creosote plants. The use of water-based preservatives may cause emissions to air, such as ammonia (if present in the preservative used).

Traffic on site and combustion processes used to produce heat or steam may result in emissions to air (carbon, NO<sub>x</sub>, SO<sub>2</sub>, and dust). In cases where thermal oxidation of VOC-containing waste gases is applied as end-of-pipe treatment, this contributes to the emissions to air.

***Emissions to water***

The use of hazardous chemicals as wood preservatives implies the risk of emitting these substances to water. Drips and spills from any area where wood preservatives are being delivered, stored, mixed, handled or applied and from freshly treated wood might get mixed with precipitation water and lead to contaminated surface run-off water. The contamination depends on the chemicals used and their composition. Substances that might be emitted from wood preservation include: tributyltin, sodium trichromate, copper salts, chromium (III), chromium (VI) oxide, ammonia, organic biocides, toluene, xylene, polycyclic aromatic compounds and creosote.

Impregnation processes using water-based salt or emulsion concentrates are basically waste-water-free processes. Secondary containment and recirculation systems are used to prevent condensates and cooling water from the impregnation plant or surface water contaminated with aqueous preservatives from entering the soil, the groundwater or adjacent watercourses. The water collected or retained can be returned to the production process (closed circuit).

In pressure treatment plants using impregnating oils (creosote), waste water streams are generated only in the form of condensates during depressurisation of the treatment vessel and during the vacuum periods. The condensates are collected, allowed to settle and treated in an activated carbon filter. The treated water is either reused (closed circuit) or discharged into the public sewer system. [VDI 3462 draft 2014], [DE BAT study 2013]

Condensates from steaming and drying processes, unless they are recirculated to the process, may lead to waste water emissions.

### ***Odour***

Odour emissions are mainly associated with creosote plants due to the naphthalene content of creosote. In water-based impregnation, sometimes the use of ammonia agents can cause some odour impacts on the environment.

### ***Contamination of the soil and pollution of groundwater***

As for the potential emissions to water, areas of chemical delivery, storage, mixing, handling, application and storage of freshly treated wood run the risk of soil and groundwater pollution if spills and drips occur and are not properly collected. Prevention of leaks and accidental spills is considered a major issue for the WPC sector.

### ***Waste***

Wood impregnation plants may produce relatively small amounts of various non-hazardous and hazardous wastes. Non-hazardous wastes include, for example, untreated wood waste and uncontaminated packaging. Hazardous wastes may include out-of-date and contaminated chemicals, redundant preservative solution, chemical packaging, contaminated wiping materials, sawdust or other materials used to soak up spills, absorbent, sludge and debris from tanks and process equipment, etc.

### ***Energy***

The most energy-consuming process is the impregnation under pressure (pressure/vacuum pumps) and the heating of creosote.

### ***Noise***

Some noise may arise from wood preservation activities, mainly related to traffic and loading/unloading activities or the mechanical processing of wood. Blowing into silos from road tankers can create noise, disturbances such as pump noise, and resonance in pipework.

## 15.2 Applied processes and techniques on wood preservation

*The section 18.2 of the 2007 STS BREF has been replaced by the following:*

### 15.2.1 Overview

The treatment processes for wood and wood products can be categorised by the type of preservative application process (non-pressure or pressure process) and/or by the type of preservative used (water-based or solvent-based preservatives or creosote).

**Non-pressure processes comprise** immersion processes (through impregnation (dipping) and hot-cold baths) and superficial treatments (such as brushing, spraying, deluging and brief dipping).

**Pressure processes** comprise a variety of processes based on autoclave treatment differing mainly in the sequence and numbers of high-pressure and low-pressure / vacuum steps applied during the impregnation process. The processes currently employed in commercial practice are:

***(High)-Pressure:***

- full-cell impregnation process/vacuum pressure process;
- alternating pressure process (Hendricksson process);
- modified alternating pressure process ('Hamburger process');
- Rueping process;
- double Rueping process;

***Low-pressure:***

- double vacuum process;
- modified Lowry process.

### **Wood preservation with water-based preservatives (WB)**

The water-based wood preservatives include boron salts (inorganic boron), CC salts (chromium-copper compounds), CCB salts (chromium-copper-boron compounds), Quat salts (quaternary ammonium compounds), Quat-boron formulations (with boron, and quaternary ammonium compounds), chromium-free copper formulations (Cu-boron, and Cu-HDO formulations, Cu, boron and triazole compounds, Cu-Quat) and formulations containing combinations of organic substances (for example, triazoles, pyrethroids carbamate). [DE BAT study 2013]

Copper-organic preservatives are generally suitable for use classes 1–4 and are applied by high-pressure processes. They are suitable for situations where timber is exposed to a high risk of biological attack, e.g. fencing, path edge boards, timber embedded in masonry. The treatment will cause timber to swell, raise the grain and may cause some distortion. [WPA Manual 2012]

Organic preservatives are suitable for use class 3 (uncoated and coated), ideally for external landscape and cladding timbers, but can also be used in use classes 1 and 2. They are applied by high-pressure processes. The treatment will cause timber to swell, raise the grain and may cause some distortion. [WPA Manual 2012]

Microemulsions (water-based) are generally restricted to use classes 1, 2 and 3 (coated), and ideally suited for internal construction timbers. They are normally applied by low-pressure (double vacuum) processes. Although water-based, the treatment has little effect on the dimensions of timber but may raise the grain. They can be used on joinery items where surface appearance is not of prime importance. Where applied by high pressure, the treatment will cause the timber to swell, will raise the grain and may cause some distortion. [WPA Manual 2012]

Water-based copper chromium arsenic (CCA) products have been used as preservatives. Since 2006 CCA is no longer authorised for use in the EU as biocide (according to Directive

98/8/EC). [Guidance 12 Wood impregnation 2007] Also, pentachlorophenol (PCP) - which was used as a preservative – was banned under the Stockholm Convention on Persistent Organic Pollutants (2015 amendment).

### Wood preservation with solvent-based preservatives (SB)

Solvent-based preservatives refer to preservative solutions where the active ingredients are carried by organic solvents (also commonly known as light-organic-solvent-based products (LOSPs)). They are generally restricted to use classes 1, 2 and 3 (coated) and applied by low-pressure processes. Their main advantage is that they do not change the dimensions of timber or raise its grain, thus making them particularly suitable for joinery components. [WPA Manual 2012]

### Wood preservation with creosote (oil-based) preservatives (C)

Creosote and coal tar creosote are complex mixtures of coal tar derivatives. They are mixtures of hundreds of distinct chemicals rather than one specific chemical. Due to their classification as carcinogenic substances, the use of creosote in wood preservation is restricted to professional use only and to specific outdoor uses. Creosote is suitable for timbers to be used externally, above and below ground and in contact with water (use classes 3 (uncoated), 4 and 5). It is applied by high-pressure processes. Treatment with creosote reduces moisture movement in timber. [WPA Manual 2012]

The **supercritical carbon dioxide process** constitutes a special case, with the carrier medium for the preservatives (active ingredients) being CO<sub>2</sub> gas in a supercritical state. In 2017, only one plant in Europe was reported to apply this preservation process.

Other chemicals used in wood preservation include chemicals for waterproofing (e.g. oils, emulsions, wax), fire retardants and chemicals used in chemical wood modification or hydrophobisation (like acetic anhydride, furfuryl alcohol, silicones and others). Chemical wood modification and hydrophobisation are not covered in this BREF (refer to Scope section).

The wood preservation process consists in principle of the following basic process steps/areas.

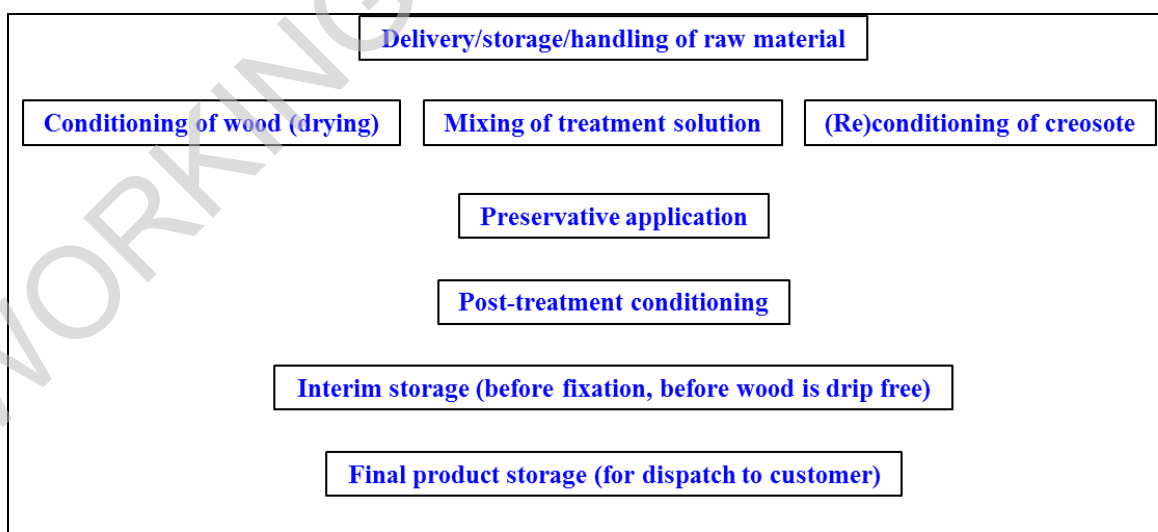


Figure 15.3: Overview of process steps for wood preservation

## 15.2.2 Delivery, storage and handling of raw materials

Wood and wood products to be treated are stored in the open or in roofed areas. The transportation of wood within the WPC plant is usually done by industrial forklift or by a crane. Wood preservatives/treatment chemicals are stored in original containers or in an approved container in order to minimise the risks of accidental leakages. [DE BAT study 2013]

Wood preservatives are delivered to the site as a concentrate for dilution in water or an organic solvent or in ready-to-use form not requiring further dilution (e.g. creosote).

### Preparation of preservative mixtures

No technical description provided.

### (Re)conditioning of creosote

During the treatment process, the creosote may accumulate water which has to be driven out before the creosote can be recirculated in the treatment process. The limit for water content is usually around 3 % and it is generally controlled to below 1 %.

Some plants include creosote reconditioning systems where the water is boiled off at temperatures above 100 °C (in some cases at 120 °C [Q DE-5 2017]).

Others reported that creosote reconditioning is not necessary because, due to the thermal oxidiser, the waste gas is not cooled down and the water stays as vapour in waste gas and passes through thermal oxidiser. [Q DE-9 2017]

## 15.2.3 Preparation/Conditioning of Wood

### Mechanical processing

The wood or wood product normally arrives at the wood preservation plant in a ready-to-treat form. Any mechanical processing is preferably done before the preservative treatment as – if done afterwards – it might expose untreated wood. Debarking, peeling, cutting, planing, drilling, etc. are mostly done in upstream wood processing plants, such as sawmills. However, in some WPC plants mechanical processing might take place to some degree. As the processes, the impacts and the techniques are not specific to WPC, and as sawmills are not covered by the IED, the TWG concluded not to cover these processes in this BREF.

Incising is a mechanical pretreatment process applied in WPC plants to enhance the preservative penetration and retention. In incising, rotating blades are run over the surface of the wood to create a pattern of incisions; pattern, density and depth vary depending on the product specifications.

The wood/wood product may be loaded into the treatment vessels manually or automatically. Depending on the type of treatment vessel, forklifts, push/pull trolleys, etc. are used. The wood/wood products may be loaded in packs, in cages or, when large-dimension wood components (e.g. poles) are being treated, as individual pieces.

### Conditioning (adjustment of moisture content)

For obtaining optimum wood preservation results, the wood has to have a certain moisture content/dryness. This can be achieved by seasoning (air drying), kiln drying, steam conditioning (vapour drying) or the Boulton process (heating in solvent / boiling under vacuum).

The most commonly applied process in WPC plants is seasoning, where the wood is stored in well-vented open storage yards for a certain length of time. In some plants, wood may also be dried in drying kilns. Only 4 of the 23 plants that took part in the WPC 2017 data collection reported kiln drying, mainly indirect drying (i.e. without direct contact between the combustion gases and the wood). Kilns for indirect drying are covered, depending on their size, by the LCP

or MCP BREF. One plant reported direct drying (which would be within the scope of this BREF) and steam drying, but no further information was submitted. Two plants apply the Boulton process but, again, no technical information was provided.

## 15.2.4 Preservative application processes

The preservative application processes are generally divided into non-pressure and pressure processes. Table 15.5 provides an overview of the different types of preservative application processes used for wood preservation with chemicals.

**Table 15.5: Preservative application processes used in wood preservation**

Non-pressure processes	
Brushing <sup>(1)</sup>	Superficial
Spraying / Spray tunnel	
Deluging	
Dipping / Immersion <ul style="list-style-type: none"> <li>• Brief dipping</li> <li>• Trough impregnation</li> <li>• Hot-cold bath treatment</li> </ul>	Impregnation
(High/Low-) Pressure processes	
High-pressure: <ul style="list-style-type: none"> <li>• Full cell process ('Bethell')/Vacuum-pressure process (plus variations)</li> <li>• Empty cell process (variations: Lowry, Rueping process)</li> </ul>	Impregnation
• Alternating pressure / modified alternating pressure	
Low-pressure: <ul style="list-style-type: none"> <li>• Double vacuum process</li> </ul>	

### 15.2.4.1 Non-pressure processes

#### 15.2.4.1.1 Brushing

No information submitted.

#### 15.2.4.1.2 Brief dipping

In brief dipping, the wood (either wood packages or single wood items) is immersed in the preservative solution in a soaking tank for a period of several seconds to several minutes. Then the wood is raised from the bath and held over the treatment solution tank for a certain time to drain excess preservative solution. A fixing time of the treatment solution in the wood is mandatory (fixing time under cover: minimum 4 hours). After that, the wood can be moved to storage.

Artificial/forced drying is not recommended. Natural drying takes a few days for light-solvent- and water-based preservatives up to a few weeks for heavy solvents. The drying time also varies depending on the wood's impregnability, the storage mode and the climatic conditions. [VDI 3462 draft 2014], [FR technical info 2017]

Brief dipping is predominantly used in the manufacture of windows. Figure 15.4 and Figure 15.5 depict the process.

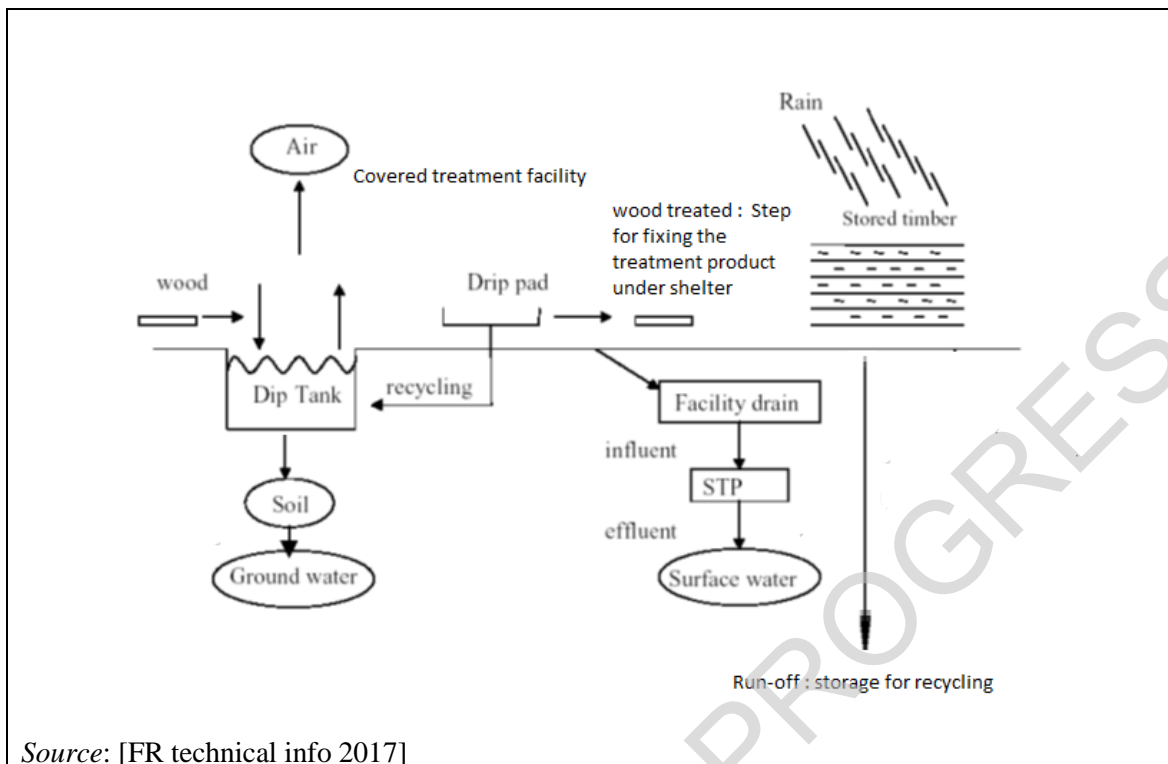


Figure 15.4: Flow diagram for the brief dipping process



Figure 15.5: Example for brief dipping - tank allowing the simultaneous treatment of several batteries with the fixing done on racks next to the dipping tank

#### 15.2.4.1.3 Deluging

In deluging, the wood is placed above a suitable liquid-impervious containment pad and the deluging lance is run over the wood by hand. The outlet opening of the deluging lance is designed so that the wood preservative exits in the form of a liquid plume, flooding the surface to be treated. Dripping and excess fluid run-off are collected and recirculated; woodchips and other coarse debris are retained in a basket-type strainer. The strainer is checked and cleaned at regular intervals. Compared to spraying, this method largely avoids the risk of mist formation. [VDI 3462 draft 2014]

## 15.2.4.1.4 Spraying/ spray tunnels

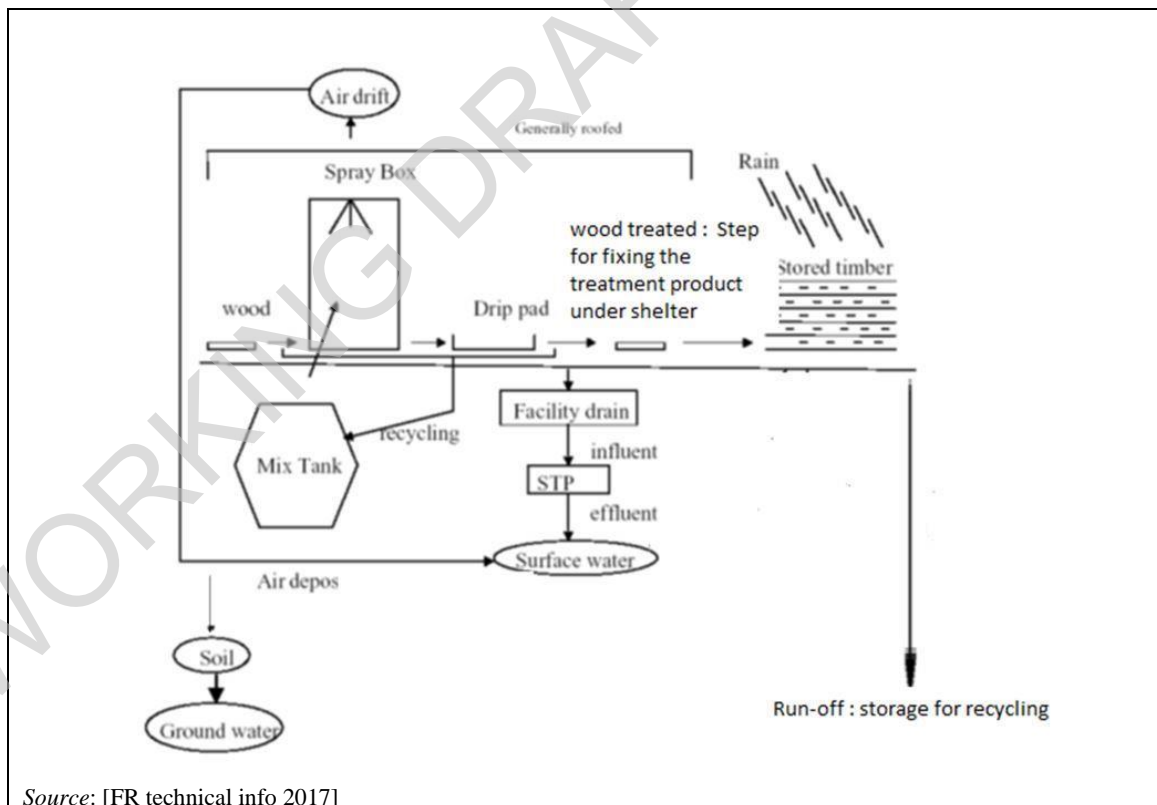
Spray tunnel systems are available as mobile and permanently installed systems. The wood (debarked logs or fully or partly machined timber) is moved through one or more longitudinal or transversal chambers on a continuously moving conveyor system. In these spray chambers, spray nozzles are arranged in such a way as to ensure that the preservative is applied to all sides of the wood as it is continuously moved through. The spray is usually coarse, i.e. particle size, to ensure the wetting of the wood with the correct amount of wood preservative. The spraying units are sealed against the ambient air. The overspray and the drippage are collected and led back to the storage tank for reuse. To ensure uniform preservative application while at the same time minimising dripping losses on the drying side, the spray chamber is usually followed by a squeegeeing device. [FR technical info 2017], [VDI 3462 draft 2014].

Splashguards surrounding the spraying boxes eliminate any droplets of spray from entering the rest of the mill area and may have local exhaust ventilation.

After the wood has been treated, it is stacked or sorted, either mechanically or manually, and dries on the conveyor belt or in the post-treatment drip-dry conditioning area before being moved off site to manufacturers or used on site.

The treatment apparatus is typically established in a contained or banded area fabricated from materials resistant to the wood preservative used. Provision is made for the collection, recycling and reuse of wood preservative collected from the conveyor or drip-dry area. The releases of wood preservatives from the treating installation or where the treated wood is stored are collected into a surface water drain or drain connected to a sewage treatment plant (STP).

Spraying is typically used in sawmills and carpentry/joinery shops. Figure 15.6 and Figure 15.7 depict the process.



Source: [FR technical info 2017]

Figure 15.6: Flow diagram for spraying / spray tunnel process



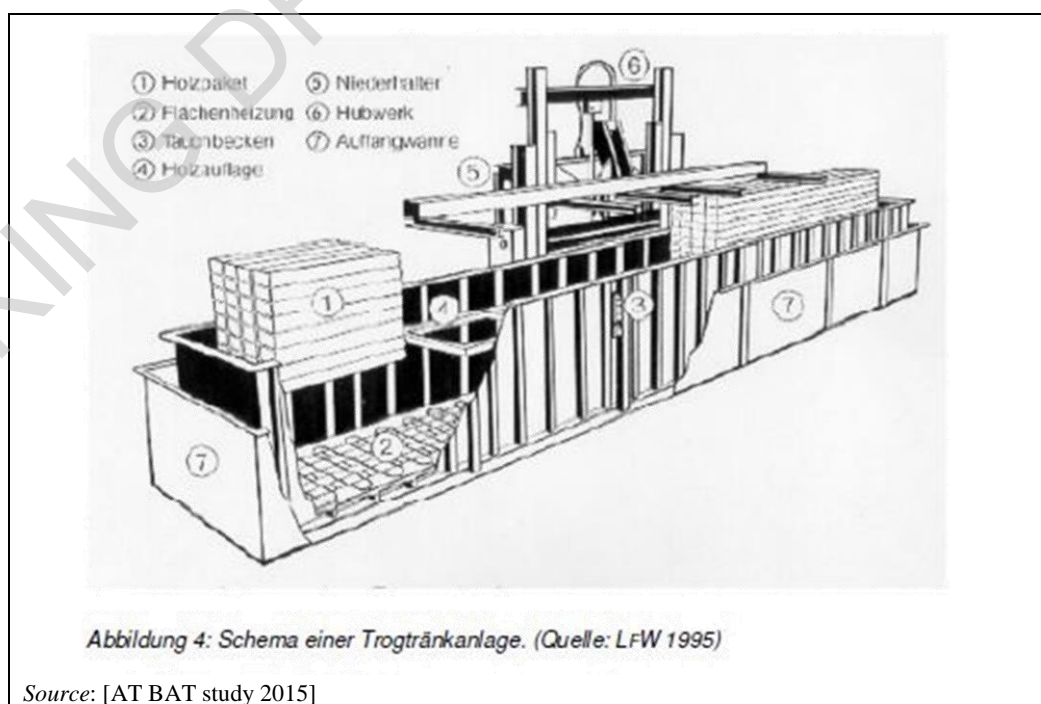


Source: [FR technical info 2017]

**Figure 15.7: Wood in closed spraying tunnel**

#### 15.2.4.1.5 Trough impregnation / dipping process

In trough impregnation, the wood is completely immersed in a tank filled with the wood preservative over a period of one to several days. In the dipping process - these days the prevalent method for treating structural timber - the wood is immersed over a period of several minutes up to several hours. Modern impregnation troughs are typically designed as double-wall tanks and provided with corrosion protection. For older single-wall impregnation tanks, a separate secondary containment system is used to ensure reliable retention of the impregnating solution in case of leakage. The trough impregnation system is installed under cover to ensure protection against precipitation. [VDI 3462 draft 2014]



Source: [AT BAT study 2015]

**Figure 15.8: Schematic of trough impregnation**

Labels in the figure will be translated to English for final figure inserted in BREF.

### 15.2.4.1.6 Hot-cold bath process

The hot-cold bath process is used for the treatment of wooden posts (supports for vineyards and orchards as well as horticulture and landscaping applications: e.g. vineyard posts, fruit tree and tree support posts). The posts are placed in the treatment tank filled with impregnating oil (creosote), the contact depth depending on the length of the post to be protected. The impregnation takes place in closed equipment (enclosure). The impregnating oil is heated to 110 °C and maintained at this temperature for 120 minutes before being cooled to a temperature of 50 °C to 60 °C (temperature difference depending of the site-specific conditions and the required level of preservative retention). When this temperature is attained, the posts are lifted out of the impregnating fluid by a lifting cage. The lifting cage is held over the treatment tank for a certain time, i.e. during the dripping and condensing phase before the system is opened. [VDI 3462 draft 2014], [DE BAT study 2013]

When the system is opened for removing the treated wood, emissions of organic and odour compounds may be released to the atmosphere. Fugitive emissions of the same compounds, although at declining concentrations, may occur during subsequent storage. [VDI 3462 draft 2014], [DE BAT study 2013]

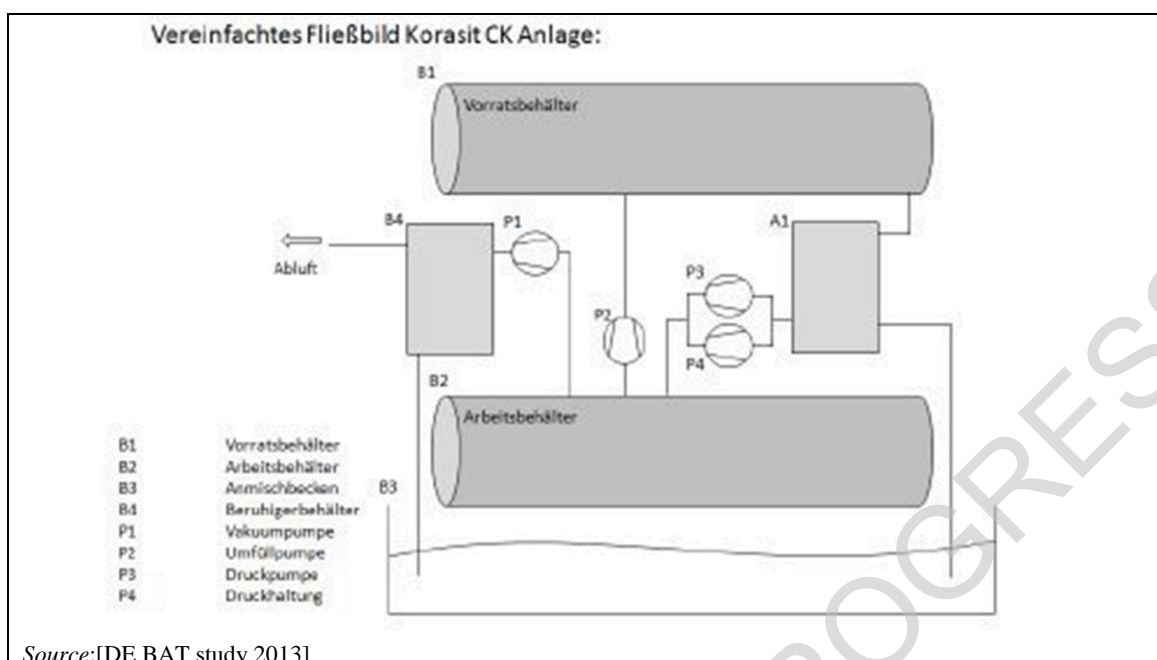
### 15.2.4.2 Pressure processes

The treatment equipment for pressure processes consists of the treatment vessel, which may be a cylindrical or rectangular pressure vessel (autoclave), and one or more storage vessels. In the case of two storage vessels, one is the working vessel which holds the preservative to flood the treatment vessel and the other is the bulk tank which is used to accept delivery of new preservative and to replenish the working/treatment vessel. The treatment vessel incorporates a loading system to enable packs of wood to be moved in and out, either manually or automatically. Loading/unloading from one end of the treatment vessel or from both ends ('roll-in roll-out') is available.

The treatment vessel door incorporates safety devices to prevent the process starting until the door is fully closed and locked and to prevent it being opened until all preservative is removed at the end of the treatment cycle.



**Figure 15.8: Example of a water-based pressure treatment plant with open mixing/storage tank**  
*Labels in the figure will be translated to English for final figure inserted in BREF.*



**Figure 15.9:** Example schematic of a pressure treatment plant for water-based preservatives  
*Labels in the figure will be translated to English for final figure inserted in BREF.*

Once the wood is loaded into the treatment vessel, the door is closed and safely locked. The treatment cycles for all pressure processes are basically variations of the following main stages, (stage 1 may be omitted or replaced with an air pressure phase, and the sequence or number of pressure phases may differ):

- 1) Initial vacuum - an initial vacuum is used to take air out of the wood. The length of this vacuum period and the level used vary according to the specification being followed. The amount of air removed will affect the final uptake and penetration of preservative. To control retention, some processes run without applying an initial vacuum.
- 2) Flooding - the preservative solution is transferred from the working vessel to the treatment vessel. If applied, the vacuum is maintained during transfer.
- 3) Pressure period - once the treatment vessel is full, the vacuum is released and, unless atmospheric pressure only is to be used, hydraulic pressure is applied using a pump. The wood is held in the preservative for a period of time. Pressure is then released in a controlled manner.
- 4) Initial drain - at the end of the pressure period, the preservative is transferred back to the working vessel.
- 5) Final vacuum - a final vacuum is applied to the wood, both to remove any excess preservative from the surface layer of the wood and to reduce dripping of the treated wood at the end of the process. As this vacuum is released, air moves back into the vessel and into the surface cells of the wood, carrying with it some of the residual preservative fluid on the wood surface. This stage may be replaced or augmented when using steam conditioning to initiate drying of the treated wood.
- 6) Final drain - during the final vacuum, the preservative collected in the treatment vessel is pumped back into the working vessel. Fresh air is often drawn through the vessel before the wood is removed to remove vapour from the working area around the door to minimise operator exposure.

#### **Creosote treatment process**

When treating wood with creosote in pressure processes (commonly 'Rueping process' or 'double Rueping process'), the treating cylinder is flooded with hot impregnating oil at a temperature of 110 °C (some reported minimum temperatures of 90 °C) to maximum 120 °C while maintaining the air pressure. Heat losses of the impregnating oil in the treating cylinder are made up by reheating to 110 °C +/- 10 °C (exchanging parts of the creosote with hot creosote). The temperature must be maintained throughout the pressure period. In the simple Rueping process, a thermal conditioning step can be carried out before proceeding to the pressure phase. Once the preliminary air pressure has been established, the wood is thermally conditioned under preliminary air pressure conditions in an impregnating oil bath for varying periods of time. Thermal conditioning raises the temperature of the impregnating oil (lower viscosity) and hence improves oil penetration into the wood. In a next step, the pressure (absolute) is increased to 9 bar at a minimum. The oil pressure level and the duration of the oil pressure period are determined by the required depth of penetration of the sapwood through to the heartwood boundary and the required preservative retention as well as by the wood species, wood condition and wood dimensions. The process ends with the depressurisation of the treating cylinder to atmospheric pressure, the return of the impregnating oil to the storage tank and the application of as high a final vacuum as possible which has to be maintained for a defined period. [DE BAT study 2013]

## **15.2.5 Post-treatment conditioning and interim storage**

### **15.2.5.1 Interim storage of freshly treated wood**

After treatment, dripping or leaching of preservative solution may occur during a variable time depending on the application process or the preservative used. Wood removed from the treatment vessel is therefore held in special areas with protective measures in place to capture drips of preservatives and/or to protect the wood from rain. Wood is only removed from these areas once it is deemed dry (drip-free) or the preservative is fixed in the wood.

### **15.2.5.2 Drying of treated wood**

#### ***a) Water-based preservatives***

High-pressure impregnation with water-containing preservatives increases the moisture content of wood. After treatment, this needs to be reduced to a level suitable for the end use of the wood. Drying may be accelerated by open stacking with good ventilation, by an increase in temperature, or by use of other means such as kiln drying. Low-pressure impregnation with water-containing preservatives will raise moisture levels only in a superficial outer zone and this is normally fully reversible by air drying within a short time. [WPA Manual 2012]

#### ***b) Organic-solvent-based preservatives***

The moisture content is not increased with treatments using organic solvent preservatives. The solvents evaporate relatively quickly providing there is adequate ventilation and good airflow. Most timbers can be used within two to seven days of treatment depending on the uptake of preservative and the prevailing conditions. Occasionally a pack of treated wood will contain some pieces which have pockets of abnormally permeable sapwood. Although undetectable before treatment, after treatment these can be seen as dark-coloured streaks. Such pieces, when identified, are removed from the pack for prolonged drying before gluing, painting or installation. [WPA Manual 2012]

#### ***c) Creosote***

Creosote is used undiluted and as such has no carrier solvent to evaporate and so does not 'dry' in the conventional sense, but as it continues to contain liquid preservative for many years it is in the nature of creosoted wood that creosote may resurface, especially when the wood is exposed to sunlight. [WPA Manual 2012]

### 15.2.5.3 Steam fixation

*In the WPC data collection 2017, 10 plants report application of 'fixation' in their questionnaires. 6 of those referred to air drying (partially under roof), 4 provided no information. TWG is asked to provide clarification on the issue of fixation vs drying and on the application of specific processes for fixating (e.g. steam fixation).*

For wood treated with non-fixating preservatives, steam fixation may be applied. The wood is put in a closed treatment vessel (without pressurisation) and 'rinsed' with steam. Fans are used to circulate the steam in the treatment vessel until the desired fixation is achieved. [DE BAT study 2013]

### 15.2.5.4 Storage of treated timber (before dispatch to customer)

After fixation and/or when treated wood is dry, it is usually removed from the treatment area and stored until dispatch to the customers. Some plants deliver their products directly to the customers ('just-in-time production'). If stored, final storage options for treated wood/wood products various from plant to plant; some apply outside storage without any special provisions, others store their products outside on hard surfaced ground/impermeable ground (with or without surface run-off collection). While some store under roof, others use plastic protection or tarpaulins to shield the wood/wood products from rain water.

### 15.2.6 Impregnating with hydrophobing agents

An option of wood enhancement is the impregnation with hydrophobisation agents such as oils, waxes or silicon compounds. Impregnation of wood with a melt of natural waxes and resins or paraffin resins significantly increases its durability and (compressive) strength. Plants of this type are operated *inter alia* in Germany, Austria, Sweden and Italy. [DE BAT study 2013], [VDI 3462 draft 2014], [Q Bitus 2017], [Q Marga 2017]

Linseed oil treatment is done in an additional process step after the conventional impregnation. The wood is placed in a separate autoclave, hot linseed oil is added and a vacuum is applied. Water evaporating from the wood is lead to a condenser. [Q Bitus 2017]

### 15.2.7 Cleaning of treatment equipment

Process vessel cleaning is a necessary stage in the treatment process. Process vessels and associated connecting pipes, pumps and filters can only be cleaned *in situ*. The range of cleaning equipment and the method used vary according to the shape of the tanks, the treatment systems concerned, the degree of cleanliness to be achieved and the quality. Fixed vessels are often cleaned using static spray heads that can be fixed into position over the top of the vessel or through a cleaning port.

Usually, organic solvent is used in such systems as the cleaning medium and is sprayed at low pressure into the top of the vessel. Other cleaning methods may involve physical techniques using brushes instead of spray heads, and manual cleaning performed from outside or directly inside the tank. Cleaning media other than solvent may include caustic solutions, water-based cleaners and abrasive impact techniques using inert particles. [UK SG11 draft 2013]

Pipelines connecting tanks are normally cleaned by flushing.

Often, it is difficult to find one machine that can clean all shapes and sizes of portable tanks and, invariably, some manual cleaning will need to be carried out, normally the external shell of the tank and valves.

Filters are cleaned either *in situ* as part of the pipe flushing/pigging process or as an open manual process under local or general exhaust ventilation. The method of cleaning will depend on the type of filter. Filter cleaning can be avoided by using disposable filters, which are available for certain pieces of equipment and are suitable for certain products. [UK SG11 draft 2013]

### 15.2.8 Other activities on site

Other activities or facilities that might be present on WPC sites, but that are not covered in detail in this BREF, comprise the following:

- **Combustion plants:** for heating purposes/steam generation (heating of creosote, steam fixation, etc.)
- **Compressor stations:** to produce compressed air for operation of the treatment facilities, valves and to seal the door of pressure treatment vessels. The plant is designed in such a way as to ensure safe operation during power cuts (ensure tightness of treatment vessel).
- **Electricity production:** pumps and compressors may be major consumers of energy/electricity, some plants generate electricity on site, examples were reported of solar-powered electricity generation (Plant DE 1: 60 000 kWh of the yearly consumption of 198 900 kWh is produced by solar panels).

### 15.2.9 Waste management

Waste management comprises all activities on site regarding waste minimisation, waste handling and on-site waste treatment. The main principles for WPC plants are reduction of the amounts of waste, especially hazardous wastes, generated; separation of hazardous and non-hazardous wastes; and reuse where feasible (e.g. preservative spills).

below provides some examples of management options.

**Table 15.6: Examples of management options for waste generated by WPC plants**

<b>Waste (type)</b>	<b>Management option</b>
	<b>Reduction</b> (of amount generated)
Contaminated wrappings from packs of wood	<ul style="list-style-type: none"> <li>• Remove before treatment</li> </ul>
Sludge/dirt and contaminated sawdust	<ul style="list-style-type: none"> <li>• Locate plant in building</li> <li>• Stabilise yard surfaces</li> <li>• Clean wood before treatment</li> </ul>
Contaminated rainwater	<ul style="list-style-type: none"> <li>• Cover plant and post-treatment conditioning area</li> </ul>
Post-treatment drippings	<ul style="list-style-type: none"> <li>• Slope packs in vessel</li> <li>• Optimise treatment cycle</li> <li>• Leave in vessel</li> </ul>
Offcuts (potentially hazardous waste)	<ul style="list-style-type: none"> <li>• Cut timber to size before treatment</li> </ul>
Treatment chemicals lost from the plant	<ul style="list-style-type: none"> <li>• Repair leaking valves, door seals, pumps</li> </ul>
Redundant treatment solution	<ul style="list-style-type: none"> <li>• Check option of another plant using up the product</li> </ul>
	<b>Reuse</b>
Collected post-treatment drippings	<ul style="list-style-type: none"> <li>• Return to plant storage tanks</li> </ul>
Unused treatment solution	<ul style="list-style-type: none"> <li>• Recover at the end of the treatment cycle and reuse</li> </ul>
Wood bearers used on bogies	<ul style="list-style-type: none"> <li>• Reuse/fit metal bearers</li> </ul>
	<b>Recycling/recovery</b>
Contaminated packaging/containers	<ul style="list-style-type: none"> <li>• Have chemicals delivered in recyclable packaging /containers and recirculate to chemicals providers</li> </ul>
Non-hazardous waste (e.g. untreated wood, paper, metal)	<ul style="list-style-type: none"> <li>• Separate components, e.g. wood, paper from metal or from inert waste</li> <li>• Sort out and collect in designated containers</li> </ul>
Untreated wood waste	<ul style="list-style-type: none"> <li>• Send off for: wood fibre recovery, energy generation or composting</li> </ul>
	<b>Disposal</b>
Treated wood waste	<ul style="list-style-type: none"> <li>• Dispose of safely (by authorised companies)</li> </ul>

### 15.2.10 Water/Waste water management

Water/waste water management comprises all activities on site regarding the prevention of waste water, handling of water streams (including surface run-off water) and waste water treatment.

Waste water can derive from process water, surface run-off water, but also from firefighting water (OTNOC). A summary of the information provided on the collection of uncontaminated rainwater / surface run-off water is given in Table 15.7 and in Table 15.8 for potentially contaminated rainwater / surface run-off water.

Table 15.7: Collection of uncontaminated rainwater / surface run-off water

Example plant	Plant type	Areas from which water is collected	Description	Water reuse	Type of discharge	Monitoring
CO2	WB	Roof area and paved surfaces	Rainwater from roof area and paved surfaces is led to the municipal sewage treatment plant via a sewer collection system	No, as no water is used in CO <sub>2</sub> process	Indirect discharge - sewer system, WWTP	No
Froslev	WB	Drying area, roof of impregnation plant and of storage facility	Via a sewer collection system	Preparation of treatment solution	NI	NI
C&G	WB+C	Entire site	Drains	No, collected water is treated in a WWTP and discharged	NI	Yes, periodical samples
WindyM	WB	Roof of treatment shed and sawmill	Rainwater is collected in two storage tanks	Preparation of treatment solution	NI	NI
Stella	WB	All uncovered site areas (including roofs of treatment line)	Internal drain network, with two main drainpipes, collected to municipal drain system and waste water treatment plant	No	Indirect discharge - sewer system, WWT plant	No
Bitus	WB	Roofs	Through pipes and collected in a pond	Preparation of treatment solution	NI	NI
PivB	WB	Output treatment area / fixation area	Pipeline to plant retention	Preparation of treatment solution	NI	NI
SNCF	C	Covered areas	Rainwater is collected from complete new tubes network	Partially, only 'process water' (steam for heating creosote) is reused	Direct discharge - surface water body	No
DE-9	WB+C	Roofs	Sedimentation basin (sludge trap) to remove dust (from the roofs), then direct discharge in canal for irrigation of fields	Not in impregnation plant, but in field irrigation	NI	NI
DE-5	C	Roofs, roads	Led to inlet area	No	NI	No
DE-8	WB+C	Roofs and surface run-off from open storage area	Storage of run-off from roofs in double-wall steel tank underground (approx. 30 m <sup>3</sup> ). Surface run-off from open storage of treated wood is treated in sedimentation basin, prior to discharge	Surface run-off from roofs is used for preparation of treatment solution	Direct discharge - surface water body	NI
DE-6	WB	Roofs and areas without dripping from freshly treated wood	Pipe system leads to a concrete basin	No	Indirect discharge - sewer system, WWTP	Yes
DE-7	WB	Roofs, storage of fresh wood	Sedimentation basin, afterwards seepage	No	NI	NI



FBI	WB+C	Separate network sewer water recuperation. All surface water is collected by a rainwater network	Separate network sewer water recuperation	Partially, recycling of water from the fixing areas to the outlet of autoclaves and storage areas under the poles (both WB & C post-treatment). Collection in two ponds. Collected water is reused for WB treatment	Direct discharge - surface water body	Yes
<i>Source:</i> [WPC data collection 2017]						

Table 15.8: Collection of potentially contaminated rainwater / surface run-off water

Example plant	Plant type	Areas from which water is collected	Description	Analyse of collected water	Where reuse	Treatment	Monitoring before discharge
Froslev	WB	Drying area, the facility	Via a sewer collection system	No	Preparation of treatment solution	NI	NI
Track	WB+C	NI	Concrete tanks 3x10 m3	Yes, by waste water company	No, disposed of as liquid waste	NI	No
C&G	WB+C	Entire site / all surface water	Drains	Yes, release from on-site WWTP is measured for: flow, Cu, Cr, PAHs, benzo[a]pyrene	No, discharged after WWTP	NI	Yes
Lonza	WB	Whole timber handling area	Water is collected from the sump area of the plant and reused directly in the mixing process	No	NI	NI	NI
Stella	WB	(Only) uncovered areas on site: dedicated to washing/and cleaning of handling machines, which are the only sources of industrial waste water discharge. Monitoring prescribed the discharge point, before mixing with domestic water/rainwater	NI	NI	NI	NI	Yes
Bitus	WB	Asphalt hard surfaces	Through pipes and ditches to a pond	Yes, twice a year water samples are sent for analysis	Preparation of treatment solution	NI	NI
Octo	WB+C	Storage areas for	An area with asphalt that has	Yes, twice a year	NI	On-site treatment	Yes

Example plant	Plant type	Areas from which water is collected	Description	Analyse of collected water	Where reuse	Treatment	Monitoring before discharge
		creosoted wood chips	collection points that lead to a sediment and oil separator	water from the separator is collected and analysed			
Oriel	WB	Inside the treatment building	Watertight sloping floor which brings any treatment water back into a sump at the bottom of the building. The sump is then emptied via a lifting pump into one of the treatment tanks	No	Preparation of treatment solution	NI	No
PivB	WB	Output treatment area / fixation area	Pipeline to plant retention	No	Preparation of treatment solution	NI	NI
SNCF	C	Areas with creosote tubes, impregnation area and covered areas for treated wood storage	Water is collected from sealed soil area and led to treatment station by tube system	No	NI	On-site treatment: active charcoal filter and reverse osmosis	No
DE-9	WB+C	Streets, open storage of impregnated wood (WB, C), turnout tracks of WB	Collected water is led to sedimentation basin (sludge trap) and then stored in a cistern for further recycling in the WB process	No	Preparation of treatment solution	NI	NI
DE-5	C	Transportation area between cooling-down building and building for putting base plates on sleepers	Collected with waterproof foil and led to waste water treatment plant	Yes, monitoring of waste water treatment plant	NI	NI	Yes
DE-6	WB	Areas where treated timber is pulled directly after unloading the treatment vessel	The impermeable hardstanding between and beside the rails for unloading the treatment vessel have a slope toward the contained area beyond the treatment vessel (collecting tray)	No	Preparation of treatment solution	NI	NI

Example plant	Plant type	Areas from which water is collected	Description	Analyse of collected water	Where reuse	Treatment	Monitoring before discharge
Marga	WB	Uncovered paved surfaces and stabilised ground surfaces, buildings, surfaces, uncovered concrete surface	By pipes carrying water to 800 mc tank	Yes, sample periodic water analysis	NI	On-site treatment	Yes
DE-7	WB	Storage of impregnated wood products	Sedimentation basin, afterwards seepage. Collection together with uncontaminated rainwater.	No	NI	On-site treatment sedimentation	No
ISB	WB	NI	Collecting seal, where the tank is on, treatment and pumped back into the tank process	No	Preparation of treatment solution	NI	No
FBI	WB+C	Injection and storage	Pond	No	Preparation of treatment solution	NI	NI

*Source:* [WPC data collection 2017]

## 15.3 Current consumption and emission levels on wood preservation

### 18.3.7 Mass balances

No data submitted.

### 18.3.2 Consumptions

#### 18.3.2.1 Materials

Each  $\text{m}^3$  of wood requires 20 kg of organic solvent based preservatives, usually white spirit or other petroleum based hydrocarbons. These consist of about 90 wt % VOC.

For the preservation of  $1 \text{ m}^3$  of wood, an average of 100 kg of creosote is required. The creosote contains 20 wt % VOC and a consumption of about 100–600 l/ $\text{m}^3$  redwood splint is reported (depending on the efficiency of the preservation method used).

The average density of commonly treated woods being about 500–600  $\text{kg}/\text{m}^3$  (ranging from 370 to 930  $\text{kg}/\text{m}^3$ ), although it is often assumed to be 1  $\text{kg}/\text{m}^3$  for simplicity ([www.simetric.co.uk/si-wood.htm](http://www.simetric.co.uk/si-wood.htm)).

For pesticides in preservative systems, see Emissions, Section 18.3.3 below. Other references can be found identifying individual pesticides and systems [150, UKHSE, 2006].

### 15.3.1 General overview of inputs and outputs of WPC plants

Figure 15.10 gives an overview of the main inputs/consumption and outputs/emissions for the preservation of wood and wood products with chemicals.

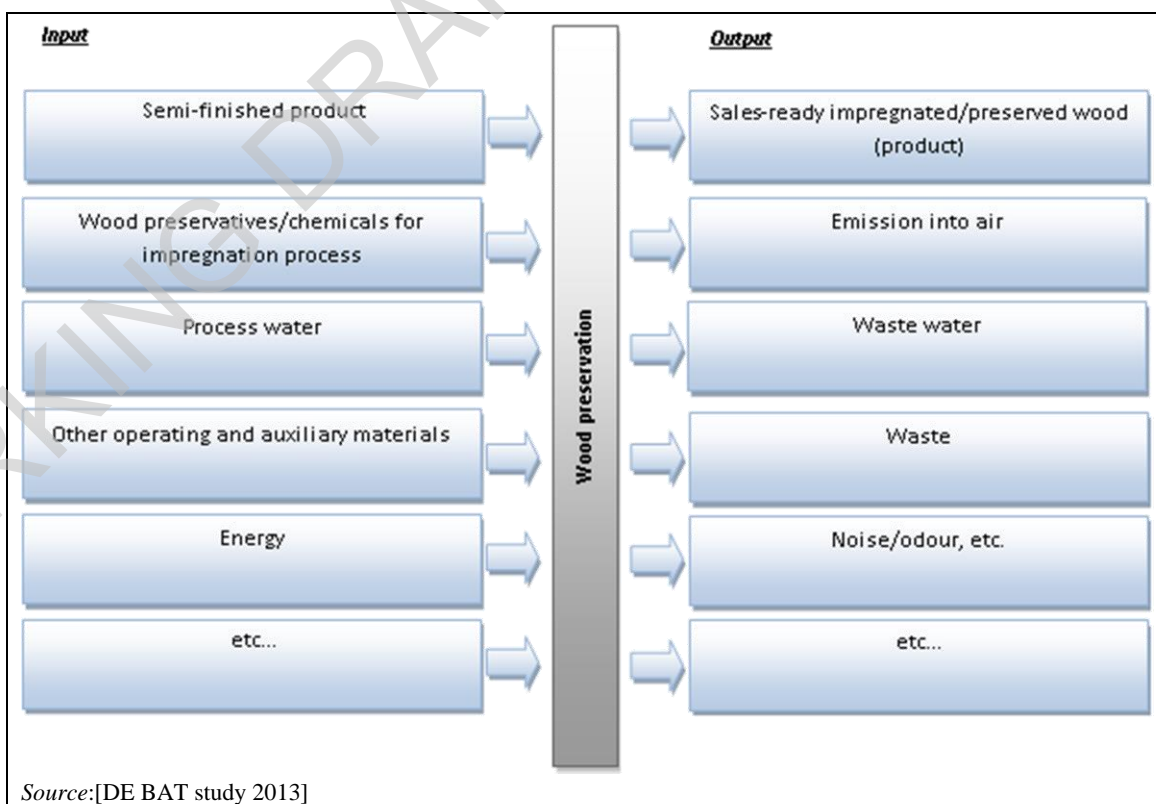


Figure 15.10: Typical input and output for wood preservation plants

*Some relevant aspects are missing, e.g. emissions to soil/groundwater in Fig 17.11, figure needs to be amended.*

Chemicals used in wood preservation comprise biocides and the corresponding 'carrier chemicals': water, solvents, CO<sub>2</sub>, but also chemicals used for waterproofing (e.g. oils, emulsions), fire retardants and chemicals used in chemical wood modification or hydrophobisation (like acetic anhydride, furfuryl alcohol, silicones). As chemical wood modification (CWM) and hydrophobisation are excluded from the scope of this BREF, these chemicals are not covered in the following sections. However, some information and data on these chemicals may be given in the sections on the BAT candidates dealing with CWM and hydrophobisation.

An overview of types of wood preservatives and the wood preservation process they are used in is presented in Table 15.9.

**Table 15.9: Overview of wood preservative types and preservation processes applied**

Wood preservation process		Wood preservative type employed	
Pressure processes	Retort pressure treatment processes	Vacuum-pressure process	Water-soluble salt concentrates
		Alternating pressure process	Water-soluble salt concentrates
		Rueping process	Impregnating oil (creosote) or emulsion concentrates based on impregnating oil (creosote)
		Double Rueping process	Impregnating oil (creosote) or emulsion concentrates based on impregnating oil (creosote)
	Low-pressure processes	Double vacuum process	Solvent-based preservatives
Non-pressure processes	Immersion processes	Trough impregnation	Water-dilutable salt concentrates and water-dilutable emulsion concentrates
		Dipping	Water-dilutable salt concentrates and water-dilutable emulsion concentrates
		Hot-cold bath treatment	Impregnating oil (creosote)
	Superficial processes	Brief dipping	Ready-to-use aqueous products
		Deluging	Ready-to-use aqueous or water-dilutable products, solvent-based products in exceptional cases
		Spray tunnel	Water-dilutable salt concentrates or ready-to-use aqueous salt solutions, predominantly boron salt formulations
		Spraying	Water-based formulations for preventive treatment at manufacturing plants; for use in closed systems only
		Brush application	Ready-to-use water-based products

Source:[DE BAT study 2013]

## 15.3.2 Inputs and consumption

### 15.3.2.1 Wood input

Different wood types with insufficient or without natural resistance to wood-destroying or wood-staining organisms for the specific end uses are impregnated. In regard to quantitative relevance, species such as pine and spruce are important. In addition, beech, oak and other wood species are used.

The wood species to be treated has an impact on the impregnability, biocide consumption and/or treatment class/use class achievable by certain biocide amounts or preservation techniques.

However, the information provided during the data collection does not allow for any reliable statements on consumption in relation to the wood species or the amounts treated.

### 15.3.2.2 Biocides consumption

Wood preservatives consist of preparations which contain one or more biocides (active substances). Biocides/biocidal products are regulated by the Regulation (EU) 528/2012, the BPR (repealing the Biocidal Products Directive 98/8/EC). According to the BPR, all biocidal products require an authorisation before they can be placed on the market, and the active substances contained in that biocidal product must be previously approved. There are, however, certain exceptions to this principle. For example, biocidal products containing active substances in the Review Programme can be made available on the market and used (subject to national laws) pending the final decision on the approval of the active substance (and up to three years after). Products containing new active substances that are still under assessment may also be allowed on the market where a provisional authorisation is granted. [ECHA website 2017]

As the products and/or active substances which are authorised may change over time, no list of currently authorised biocidal products or active substances is given in this BREF. Instead the reader is referred to the relevant and up-to-date website of the European Chemicals Agency – ECHA (<https://echa.europa.eu/regulations/biocidal-products-regulation>, *status 2017*)

The specific biocide consumption per m<sup>3</sup> of wood treated reported during the data collection for this BREF (2017) for water-based preservative treatment and one CO<sub>2</sub> process is summarised in

Table 15.11. No data were reported for solvent-based wood preservation.

The data submitted do not allow for detailed figures for certain active substances or chemical components in the biocidal products, but a non-exhaustive overview of the ingredients of the biocidal product types - that are used in the plants that took part in the data collection - is given in Table 15.10 below.

**Table 15.10: Non-exhaustive overview of ingredients of biocidal product types used in plants that took part in the WPC 2017 data collection**

Biocidal product type	Exemplary ingredients
a	- basic copper carbonate, - 2-aminoethanol, - quaternary ammonium compounds, - benzalkonium chloride, cyproconazole
b	- copper, - quaternary ammonium compounds, - boric acid
c	- copper hydroxide carbonate - N, N-Didecyl-N methylpoly (oxyethyl) ammonium propionate
d	- copper carbonate, - 2-aminoethanol, - boric acid, - tebuconazole, propiconazole, - polyethyleneamine - organic acids and surfactants
e	- propiconazole, tebuconazole, permethrin
f	- propiconazole, tebuconazole
g	- bis-(N-cyclohexyldiazoniumdioxy)-copper, - copper hydroxide carbonate - boric acid, - 2-Aminoethanol
h	- Permethrin, propiconazole



Table 15.11: Reported biocide consumption for water-based preservative treatment

	Process	Commodities	Penetration class (EN 351)	Use class	Specific biocidal product consumption (kg/m <sup>3</sup> )	Biocidal product type
<b>CO<sub>2</sub> plant</b>	Pressure process (autoclave)	Exterior walls and joinery, posts	NI	UC 2 UC 3	1	f
<b>Froslev</b>	Pressure process (autoclave)	Exterior walls and joinery, posts	NI	UC 1 UC 3 UC 3 UC 4	8 (for UC 3) 16 (for UC 4)	d
<b>Track</b>	Pressure process (autoclave)	Poles	NP 5	UC 4	8.94–13.69	g
<b>C&amp;G</b>	Pressure process (autoclave)	Poles, sleepers, posts, fence rails / decking boards	NP 3 NP 5 NP 6	UC 3 UC 4	18.31–28.38*	NI
<b>WindyM</b>	Pressure process (autoclave)	Fence rails / decking boards, posts, sleepers, exterior walls and joinery, purlins	NI	UC 1 UC 2 UC 3 UC 4	3.52	a
<b>Bitus</b>	Pressure process (autoclave)	Fence rails / decking boards	NP 5 NP 2	UC 3 UC 4 UC 2	2.28–3.08	a, d, g
<b>Varberg</b>	Pressure process (autoclave)	NI	NP 1 NP 5	UC 1 UC 3 UC 4	6.74–8.64	a, b
<b>Oriel</b>	Dipping /Immersion	Internal building timbers	NP 1	UC 2	0.309–0.322*	h
<b>Piveteau</b>	Pressure process (autoclave)	Internal joinery, internal building timbers, exterior walls and joinery, fence rails / decking boards, posts, poles	NP 5 NP 3	UC 4 UC 3	7.5*	NI
<b>DE-6</b>	Pressure process (autoclave)	Poles, sleepers, posts	NP 5 NP 4 NP 3 Others	UC 4 UC 3	14.500	g, c
<b>ISB</b>	Dipping /Immersion	Internal building timbers	NP 1	UC 2	1.005–1.034	NI

\* calculated from reported data.  
 NB: a – g: Biocidal product types.  
 NI = no information.  
 Source: [WPC data collection 2017]

### 15.3.2.3 Creosote consumption

Creosotes are distillate fractions consisting of a multitude of chemical compounds. They are differentiated into three types (types A - C, according to EN 13991) with different vapour pressures. According to the IED, the fraction of creosote which exceeds the value of 0.01 kPa vapour pressure at 293.15 K shall be considered a VOC. The VOCs are the low-boiling fraction of the creosote. [Guidance 12 Wood impregnation 2007]

The use of creosote is restricted to wood for outdoor applications with special requirements (ground contact), e.g. posts, poles, fencing or sleepers (Directive 76/769/EEC), due to its classification as a carcinogenic Category 2 substance because of its benzo[a]pyrene content. According to Directive 2001/90/EC, if the product contains less than 0.005 % (by mass) benzo[a]pyrene and less than 3 % (by mass) water-extractable phenols, it may be used, but only in industrial installations or by professionals. Therefore Type A creosote, which can now contain 0.005 % to 0.05 % and formerly contained up to 0.1 % benzo[a]pyrene, is banned in the EU. [Guidance 12 Wood impregnation 2007]

Type B creosote is currently the most widely used oil-based wood preservative used, with an average VOC content of 20 % and less than 0.005 % benzo[a]pyrene.

Type C creosote, with a much reduced VOC content (~2%), and a content of less than 0.005 % benzo[a]pyrene has a high viscosity and high crystallisation temperature. Therefore it is necessary that the storage and impregnation system is heated. The advantages are the lack of odour and reduced tendency for the wood to sweat. [Guidance 12 Wood impregnation 2007]

For the preservation of 1 m<sup>3</sup> of wood, an average of 100 kg of creosote is required. The creosote contains 20 wt-% VOCs and a consumption of about 100–600 l/m<sup>3</sup> redwood splint is reported (depending on the efficiency of the preservation method used). [STS BREF 2007] Other sources claim a range of 40 kg to 150 kg of creosote is needed for the impregnation of 1 m<sup>3</sup> of wood. [Guidance 12 Wood impregnation 2007]

Some exemplary data for creosote plants applying pressure treatment or hot-cold bath treatment as provided in a BAT study submitted by Germany are presented in Table 15.12 below.

**Table 15.12: Exemplary plant data for creosote treatment plants**

Plant data	Unit	Range for hot-cold bath treatment process	Range for pressure processes
Preservatives used		Impregnating oil (Grades B and C according to DIN EN 13991)	Impregnating oil (Grades B and C according to DIN EN 13991)
Volume of treating cylinder or tank	m <sup>3</sup>	10–15	20–100
Impregnating oil consumption <sup>*)</sup>	kg/h	15–18	34–116 (e.g. for wooden posts or paddock fence elements)  58–211 (for railway sleepers)
Timber throughput <sup>**)</sup>	m <sup>3</sup> /h	0.16–0.21 (related to treated components)	0.5–0.9 (e.g. for wooden posts or paddock fence elements)  1.5–2.4 (for railway sleepers)
<sup>*)</sup> The impregnating oil consumption indicated relates to the timber volume that can be treated within 24 hours, depending, among other factors, on the impregnation process and the wood species. <sup>**)</sup> The timber throughput indicated relates to the timber volume that can be treated within 24 hours, depending, among other factors, on the impregnation process and the wood species. Source: [DE BAT study 2013]			

The specific creosote consumption (i.e. consumption of creosote per m<sup>3</sup> of wood treated) reported during the data collection for this BREF (2017) for pressure treatment processes are summarised in Table 15.13. For non-pressure processes no data were reported.

**Table 15.13: Specific creosote consumption for creosote pressure treatment (reporting period 2014–2016)**

Plant	Commodities	Wood species treated	Creosote type	Penetration class (EN 351)	Use class	Creosote consumption (kg/m <sup>3</sup> )
Track	Sleepers, wooden bearers	Beech, pine, oak	B, C	NP 5	UC 4	85–94
C&G	Poles, sleepers, posts, fence rails / decking boards	Pine, Douglas fir, larch, spruce	NA	NP 5	UC 4	141–213 <sup>(1)</sup>
Octo	Poles, posts, sleepers	Pine	B	NP 5	UC 4	91–101
SNCF	Sleepers	Oak	C	NP 5	UC 4	33–36
DE-5	Sleepers	Beech, oak	C	NP 6, NP 4	UC 4	81–89
FBI	Poles	Spruce	B	NP 4	UC 4	141–163

<sup>(1)</sup> Upper end seems atypically high, compared to 141 kg/m<sup>3</sup> and 143 kg/m<sup>3</sup> reported for the other years.  
 NB: NA = no information provided.  
 Source: [WPC data collection 2017]

### 15.3.2.4 Water consumption

Water is used for preparing the treatment solution in water-based wood preservation, for steam production for drying wood, for steam fixation and for heating creosote.

The water consumption reported during the data collection for this BREF (2017) for wood preservation plants is summarised in Table 15.14.

**Table 15.14: Reported water consumption for water-based treatment processes for 20014 – 2016**

*(Data reported in questionnaire is still under validation (e.g. for units used))*

	Specific water consumption (m <sup>3</sup> /m <sup>3</sup> treated wood)	Yearly water consumption for preparation of preservative solution (m <sup>3</sup> )
Froslev	0.308	18 500
Track	0.316–0.331	335 - 565
Lonza	0.100–0.127	877 – 1 000
Lonza	0.012	15 - 24
Sodra	0.012	204 - 372
Bitus	0.131–0.136	19 775 – 21 662
Varberg	0.168–0.190	6 174 – 7 040
Octo	0.357	4 800 – 6 300
Oriel		420 - 545
Piveteau	0.299-0.300 0.069-0.07	14 171 – 18 423 106-262
Paras		7 000 – 7 337
DE-6	0.300	2 550 2 850
ISB	0.017–0.018	508 - 585

Source: [WPC data collection 2017]

### 15.3.2.5 Solvent consumption

Each m<sup>3</sup> of wood requires 20 kg of organic solvent based preservatives, usually white spirit or other petroleum based hydrocarbons. These consist of about 90 wt % VOC.

Solvent-based preservatives contain approximately 5 % of active ingredient (insecticides, fungicides or water repellents) and 95 % organic solvent. Approximately 20 kg are needed for the impregnation of 1 m<sup>3</sup> of wood.

Nowadays the so-called LOSP - light organic solvent preservatives - are used. In these preservatives, organic solvents such as white spirit or other petroleum-based hydrocarbons are used as solvents to carry the active ingredients (e.g. fungicides, insecticides, water repellents) into the wood. White spirit consists mainly (> 80 %) of C<sub>9</sub>-C<sub>11</sub> hydrocarbons (aliphatics, alicyclics and aromatics), the remainder is largely C<sub>7</sub>-C<sub>8</sub> and C<sub>12</sub> hydrocarbons. [Guidance 12 Wood impregnation 2007]

No solvent-based treatment plant took part in the data collection for the review of this BREF. Therefore no data can be provided on the solvent consumption of such WPC plants.

A water-based plant and the supercritical CO<sub>2</sub> plant provided information on solvent consumption, albeit without an explanation of what the solvents are being used for. The water-based plant reported a specific organic solvent consumption of 0.033 kg/m<sup>3</sup> of treated wood, the majority of this amount (95 %) represents dipropylene glycol monomethyl ether, the rest is acetic acid. The CO<sub>2</sub> plant reported a specific solvent consumption of 0.8 kg/m<sup>3</sup> of treated wood, basically glycol ether.

It should be noted that biocidal products used for water-based wood preservation may contain some solvents, but no specific information or data was provided.

### 15.3.2.6 Other impregnating chemicals consumption

If the enhancement agents used in wood hydrophobisation contain either aqueous emulsions or melts of hydrophobisation agents, no relevant emissions are expected from this process. However, no data from dedicated studies are currently available.

If liquid organic hydrophobisation agents (e.g. paraffins) are used, special aspects with regard to VOCs need to be considered. [DE BAT study 2013], [VDI 3462 draft 2014]

### 15.3.2.7 Auxiliary materials consumption

Oil, grease and lubricants are used very small quantities in WPC. [DE BAT study 2013]

### 15.3.2.8 Energy consumption

The energy consumption of a WPC plant depends on the plant type and the process(es) applied. The TWG identified energy consumption and efficiency for creosote processes and autoclave processes as a key environmental issue (KEI). It was concluded to include in the information and data collection energy consumption (total consumption and specific/production-related consumption in kWh/m<sup>3</sup> wood/wood product) and energy efficiency together with the relevant contextual information (including the process boundaries used). However, very few data were submitted on these issues.

Table 15.15 provides an overview of the data on energy consumption and the related contextual information reported during the WPC 2017 data collection.

Table 15.15: Reported energy consumption for wood preservation [WPC data collection 2017]

Source: [WPC data collection 2017]			

Information from WPC 2017 data collection (questionnaires) to be added.

### 15.3.3 Outputs and emissions

#### 15.3.3.1 General overview of emissions

##### Emissions for SB WPC plants

(TWG is asked to check suitability of the Figure below for the revised STS BREF (i.e. including the whole WPC sector) and to provide more suitable figure if considered necessary. Not shown in figure are emissions to soil/groundwater.)

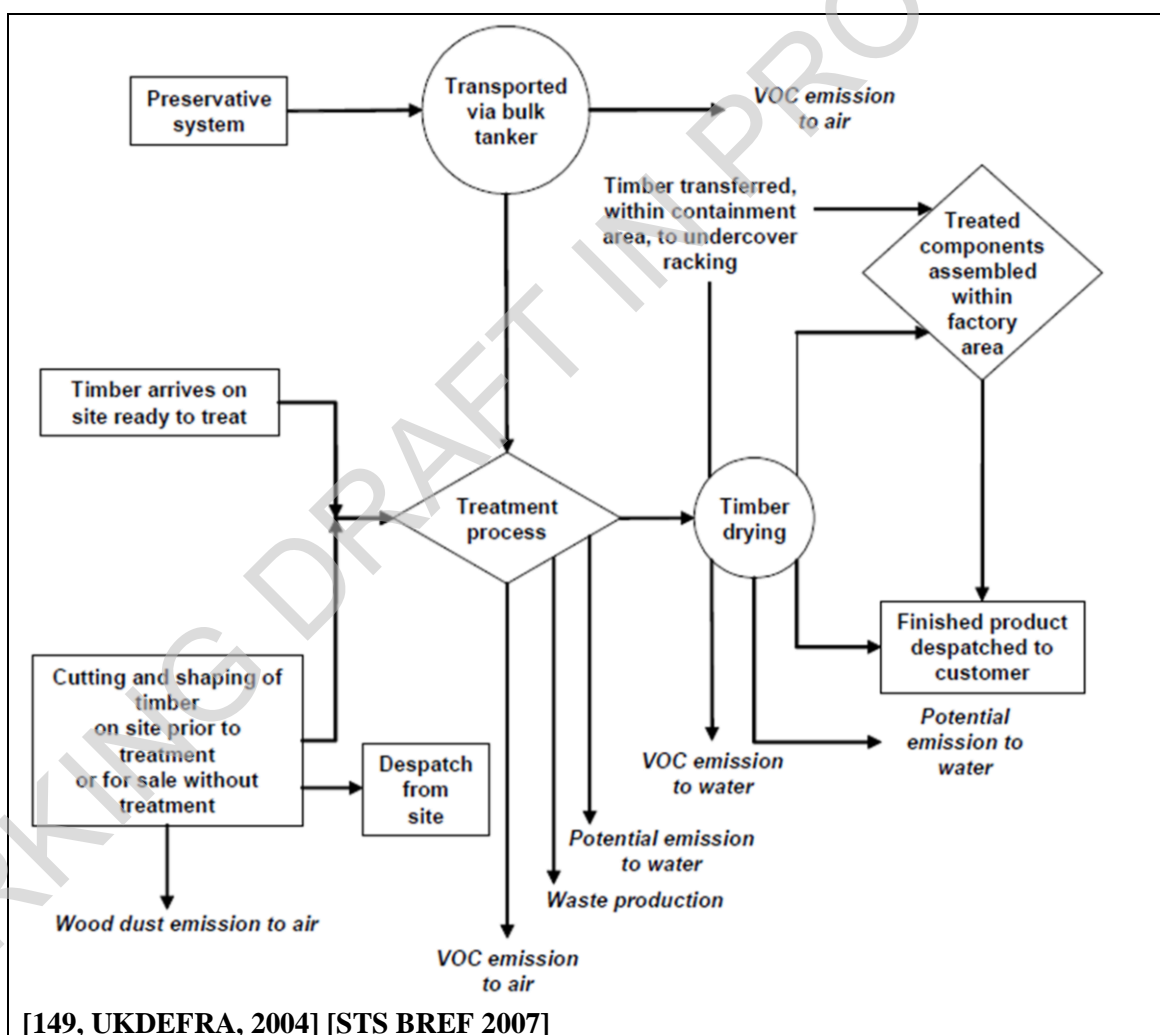


Figure 15.11: Figure 15.12: Flow diagram of typical wood preservation installation showing consumption and emissions

**15.3.3.2 Emissions to soil and groundwater****18.3.3.2 Emissions to water, soil and groundwater**

The preservatives applied in this industry are by nature ecotoxic. The industry has a history of using POPs and/or PBTs. The industry has been a significant source of some POPs, such as PAHs and PCP. PAH emissions from creosote use are important. It was reported in 1999 that wood preservation contributed 30 % of the total EU-15 POP emissions [151, EEA, 1999] [150, UKHSE, 2006].

While the use and emission of these substances has decreased due to increasing legislation and industry changes, substances such as creosote, tributyl tin, sodium trichromate and chromium oxide (hexavalent chromium), arsenic oxide, copper salts, etc. are still in use (some were banned in 2006). More information can be found in the references.

Moves to substances less harmful to human health (in manufacture and application) have led to the use of substances such as permitherins. These can have a high aquatic toxicity.

Releases of heavy metals wood preservation to soil and water could be important (arsenic, zinc, copper, tin), see above. [STS BREF 2007]

All chemicals (solvents, creosote, active substances/biocides, additives, hydrophobing agents, fire retardants, etc.) used in the wood preservation process bear the risk of being emitted to soil and eventually to groundwater as accidental releases from the processes. Chemicals that are no longer used may also still be emitted to groundwater if there is contaminated soil on site from previous WPC plant operations.

The information on potential pollutants and parameters monitored in soil and/or groundwater which was provided during the WPC 2017 data collection is summarised in Table 15.16.

**Table 15.16: Potential pollutants and parameters monitored in soil and groundwater**


*Information from WPC 2017 data collection (questionnaires) to be added.*

**15.3.3.3 Emissions to water**

In general, waste water can arise as surface run-off water, accidental releases (drips or spillages) of chemicals used in wood preservation and firefighting water. Any chemical (or constituents thereof) used in the wood preservation process may be a pollutant present in the waste water.

A summary of the information on emissions to water from WPC plants provided during the WPC 2017 data collection is given in Table 15.17.

**Table 15.17: Emission to water from WPC plants**


*Information from WPC 2017 data collection (questionnaires) to be added.*

### 15.3.3.4 Emissions to air

Emissions to air may arise from solvent-based processes and wood preservation using creosote due to the volatile compounds in the preservatives (e.g. VOCs, PAHs, odour, CMR substances, SVHC) or when waste gas treatment by thermal oxidation is applied (NO<sub>x</sub> and CO).

Aerosols (of preservatives) may be emitted for all wood preservative types (WB, SB and C) when preservatives are sprayed or at the outlet of vacuum pumps, if some of the preservative solution is extracted.

Heating of impregnating chemicals such as oil or wax may result in organic compounds emissions to air.

Emissions to air from vehicles (transport of wood on site) are considered not WPC-specific and of minor importance.

#### 15.3.3.4.1 Emissions to air from solvent-based and creosote wood preservation

*(No filled-in questionnaires were submitted for solvent-based plants. TWG members are advised that if they want SB-specific information/data, especially regarding emissions to air - and based on this - BAT-AEPLs to be included in the revised STS BREF, the relevant data should be provided.)*

#### VOC emissions

The main emission source is from the solvent content of the applied substances. ~~Fugitive and contained emissions can be reduced with the help of abatement equipment.~~ Solvents which remain in the wood after complete drying evaporate over longer periods of time. Fugitive emissions occur during handling, application and drying stages. However, the majority of the emissions occur during the drying process. [STS BREF 2007]

At an EU-25 level in 2000 (according to the RAINS model) NMVOC emissions were 54.9 kt representing 0.5 % of total NMVOC emissions (the total estimated EU-15 emission was 47.5 kt/yr in 1990). Total activity in the industry was 11.5 million m<sup>3</sup>, and the average emission factor is about 4.8 kg NMVOC/m<sup>3</sup> meaning that emissions from this sector are already partly abated in the EU-25 (the unabated emission factor being 19.8 kg/m<sup>3</sup>, see Table 15.18). The contribution to the total EU-15 VOC emissions varies significantly from country to country. [STS BREF 2007]

~~Processes using traditional solvent based preservatives are likely to need treatment with end-of-pipe techniques in order to be in compliance with the SED requirements. Two secondary measures are possible: thermal oxidation and carbon adsorption [140, EGTEI, 2005].~~

The options for reducing VOC emissions by primary (in-process) measures and secondary (end-of-pipe) measures have been estimated at a European level. The data have been taken from EGTEI's large reference installation [140, EGTEI, 2005], [STS BREF 2007]:

- wood volume to be treated: 5 000 m<sup>3</sup>/yr;
- solvent input: 99 t/yr;
- full load hours: 6 000 h/yr;
- flowrate: 22 200 m<sup>3</sup>/h.

~~Wood preservation is unlikely to be a significant source of emissions of heavy metals to the air.~~

**Table 15.18: Table 18.1: Wood preservation default emission factors (EF), abatement efficiencies and costs for each combination**

PMC Primary measure code (see Table 15.19)	SMC Secondary measure	NMVOE EF (kg/m <sup>3</sup> )	Abatement efficiency (%)	Investment (tEUR)	Variable operating costs (tEUR/yr)	Fixed operating costs (tEUR/yr)	Unit cost (tEUR/t VOC abated)	Unit cost (tEUR/m <sup>3</sup> )
00	00	19.80	0.0	0.0	0.0	-	-	0.0
00	01	7.30	63.1	1040.8	75.0	52.2	4114	51.1
00	02	7.30	63.1	494.5	21.4	24.7	1019	21.4
01	00	16.60	16.2	87.0	-11.5	-	-320	-1.0
01	01	6.10	69.2	1055.5	55.4	48.4	3293	45.9
01	02	6.10	69.2	542.9	8.4	22.8	827	18.8
02	00	11.00	44.4	102.0	-22.7	-	-346	-3.0
03	00	0.25	98.7	3.0	28.0	-	289	5.6
04	00	0.15	99.2	90.0	-12.0	-	-55	-1.1

NB: EF = emission factors.  
Source: [140, EGTEI, 2005], [STS BREF 2007]

(Information on emissions and costs for air abatement systems, to be moved to BAT candidate section 15.4.3.2.4 Waste gas treatment after verification.)

**Table 15.19: Table 18.2: Wood preservation: Primary abatement measures**

Primary measure code PMC	Description
00	100 % solvent-based preservatives conventional application techniques (dipping, brushing, spraying)
01	100 % solvent-based preservatives improved application technique (vacuum preservation system)
02	Process optimisation 100 % more concentrated solvent-based preservatives improved application technique (vacuum preservation system)
03	100 % water-based preservatives conventional application techniques (dipping, brushing, spraying)
04	100 % water-based preservatives improved application technique (vacuum preservation system)

Source: [140, EGTEI, 2005], [STS BREF 2007]

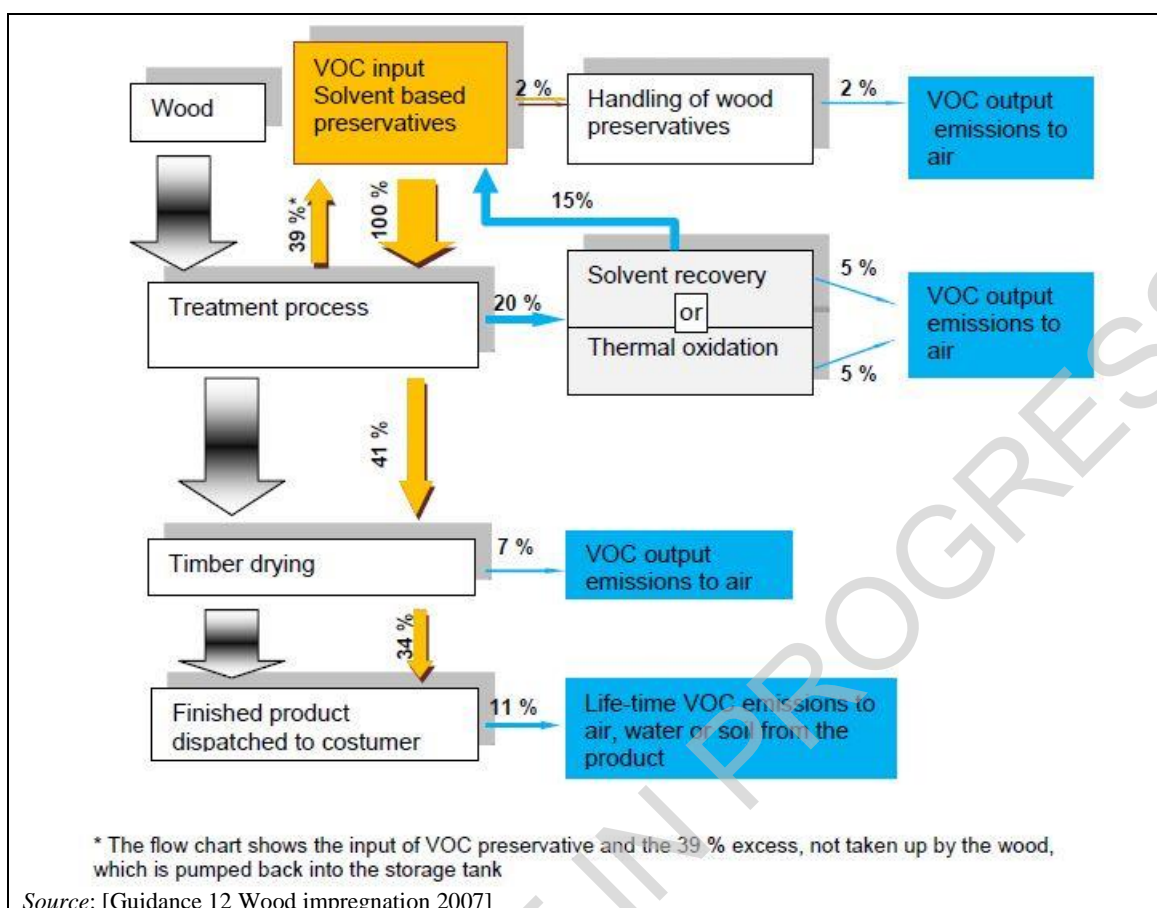
**Table 15.20: Table 18.3: Wood preservation: Secondary abatement measures**

Secondary measure code SMC	Description
00	No secondary measure
01	Thermal oxidation (see Section 20.11)
02	Adsorption and solvent recovery (see Section 20.11)

Source: [140, EGTEI, 2005], [STS BREF 2007]

The flow chart in Figure 15.13 illustrates the process steps for wood impregnation using solvent-based products and shows where VOC emissions can occur. It also provides an indication of the percentage of solvent that is emitted from each process or that remains in the products. In the case of creosote the flow chart looks similar, but solvent recovery is not possible.





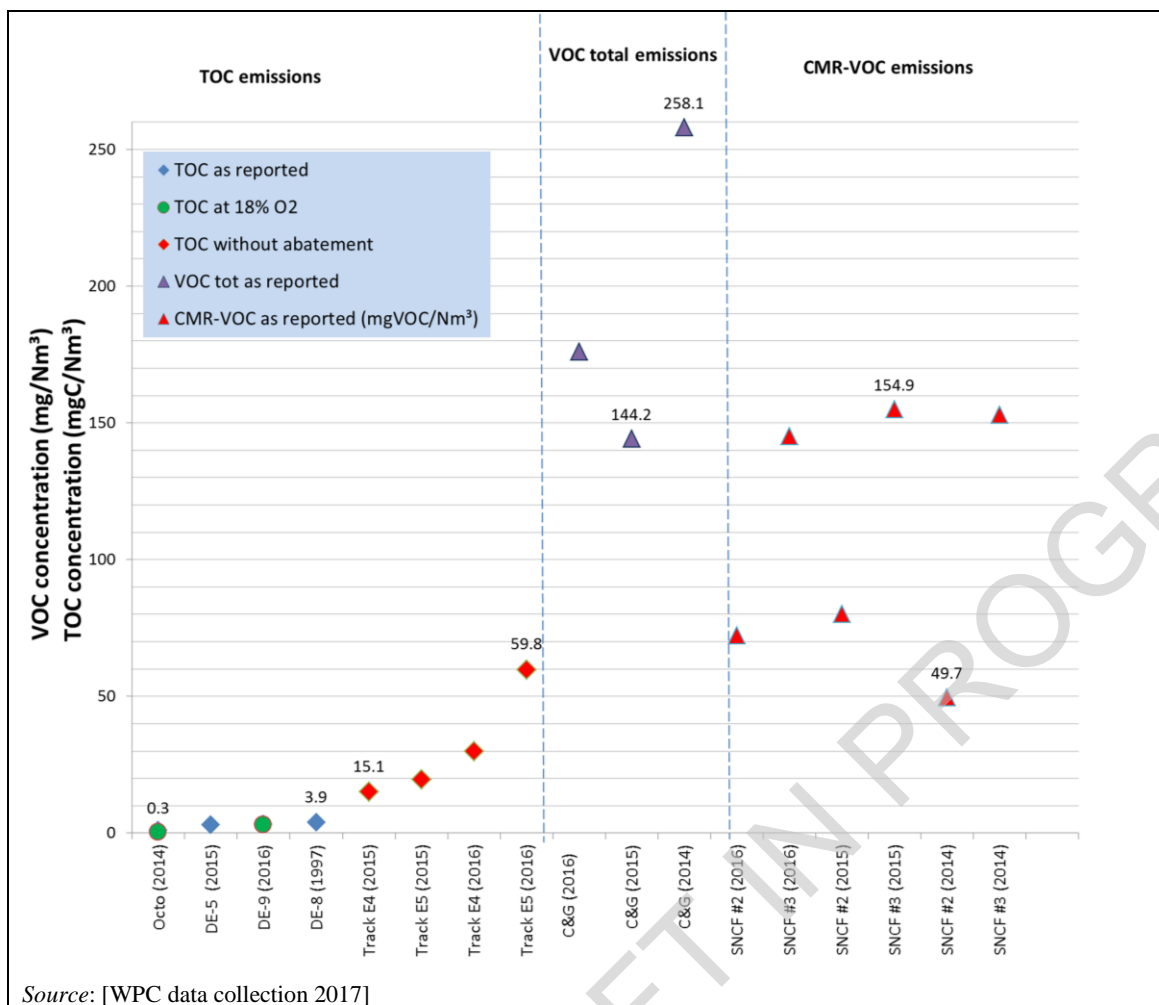
**Figure 15.13: Typical VOC inputs and outputs in wood impregnation processes using solvent-based preservatives**

Approximately one third of the solvent that remains in the wood after drying at the wood preservation plant will evaporate over time, but the other two thirds will stay in the wood over its working life.

During the WPC 2017 data collection, information was provided on VOC emissions from seven plants applying creosote treatment. The data were provided as TOC emissions (in mg C/Nm<sup>3</sup>), as total VOC emissions (in mg/Nm<sup>3</sup>) and as CMR-VOC<sup>28</sup> emissions (in mg/Nm<sup>3</sup>). The emission range reported for TOC was 0.3 mg C/Nm<sup>3</sup> to 59.8 mg/Nm<sup>3</sup>. The upper end of the range, from 15.1 mg C/Nm<sup>3</sup> to 59.8 mg C/Nm<sup>3</sup>, refers to a plant that does not apply any VOC abatement, while the lower end, from 0.3 mg C/Nm<sup>3</sup> to 3.9 mg C/Nm<sup>3</sup>, refers to plants applying a thermal oxidiser, adsorption or a scrubber. One plant incinerating the waste gases from the creosote plant together with uncontaminated wood waste in a biomass boiler reported total VOC values ranging from 144.2 mg/Nm<sup>3</sup> to 258.1 mg/Nm<sup>3</sup> (without information on the oxygen level in waste gas of the biomass boiler). Another plant provided information only on CMR-VOCs. These range from 49.1 mg/Nm<sup>3</sup> to 154.9 mg/Nm<sup>3</sup>; no emission abatement is applied at this plant. *(See also comment below for CMR emissions)*

The information on VOC emissions to air from creosote plants as reported during the WPC 2017 data collection is shown in Figure 15.14. No information on VOC emissions from solvent-based plants was submitted.

<sup>28</sup> CMR-VOCs defined for the purpose of the data collection as VOCs which are assigned or need to carry the hazard statements H340, H350, H350i, H360D, H360F or halogenated VOCs which are assigned or need to carry the hazard statements H341 or H351.) in mg VOC/Nm<sup>3</sup>.

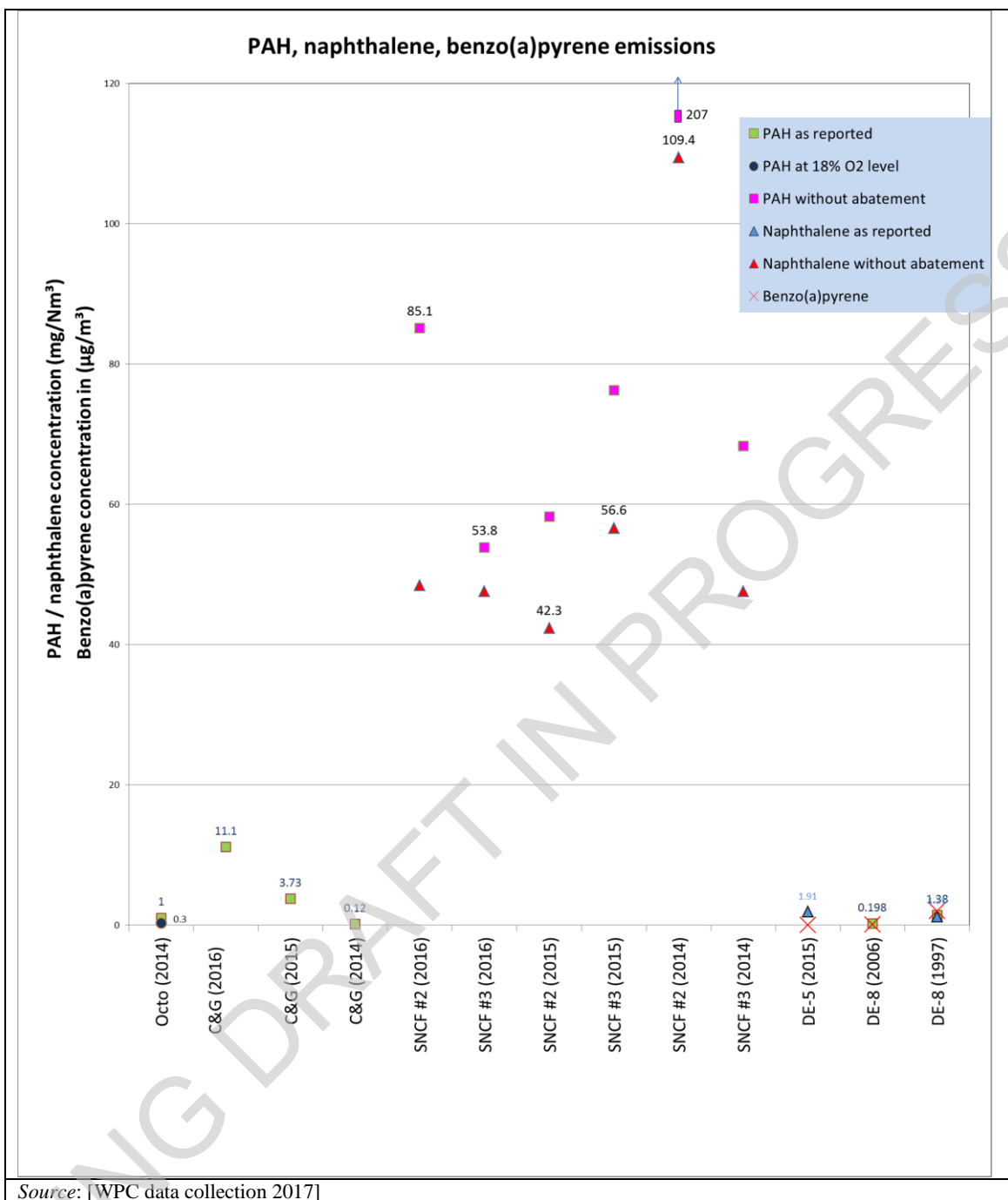


Source: [WPC data collection 2017]

Figure 15.14: Reported VOC emissions to air from creosote plants

**PAHs**

During the WPC 2017 data collection information was provided on PAHs, naphthalene and benzo(a)pyrene emissions for five plants applying creosote treatment. Reported emission values for PAHs range from < 1 mg/Nm<sup>3</sup> to 85.1 mg/Nm<sup>3</sup> (with one extreme value of 207 mg/Nm<sup>3</sup> reported). The data compilation in Figure 15.15 shows that plants applying abatement techniques make up the lower end of the range with three plants reporting values of 0.2 mg/Nm<sup>3</sup> and 1.4 mg/Nm<sup>3</sup> (for a scrubber) and 0.3 mg/Nm<sup>3</sup> (at an 18 % O<sub>2</sub> level for a thermal oxidiser) and up to 11.1 mg/Nm<sup>3</sup> (for combustion in a biomass boiler, without information on the O<sub>2</sub> levels). The one plant reporting PAH values (for two emission points) without abatement shows a clearly higher emission range starting from 53.8 mg/Nm<sup>3</sup>. For naphthalene, two plants with abatement that submitted data (one with adsorption, the other with a scrubber) reported values of 1.2 mg/Nm<sup>3</sup> and 1.9 mg/Nm<sup>3</sup>, while the plant without an abatement system reports a range of 42.3–56.6 mg/m<sup>3</sup> (with one extreme value of 109.4 mg/Nm<sup>3</sup>, corresponding to the same measurement as the peak value for PAHs above).



**Figure 15.15: Reported PAH, naphthalene and benzo(a)pyrene emissions from creosote plants**

During the kick-off meeting, the TWG concluded to include in the information and data collection fugitive emissions of PAHs. However, no information on fugitive emissions of PAHs was submitted.

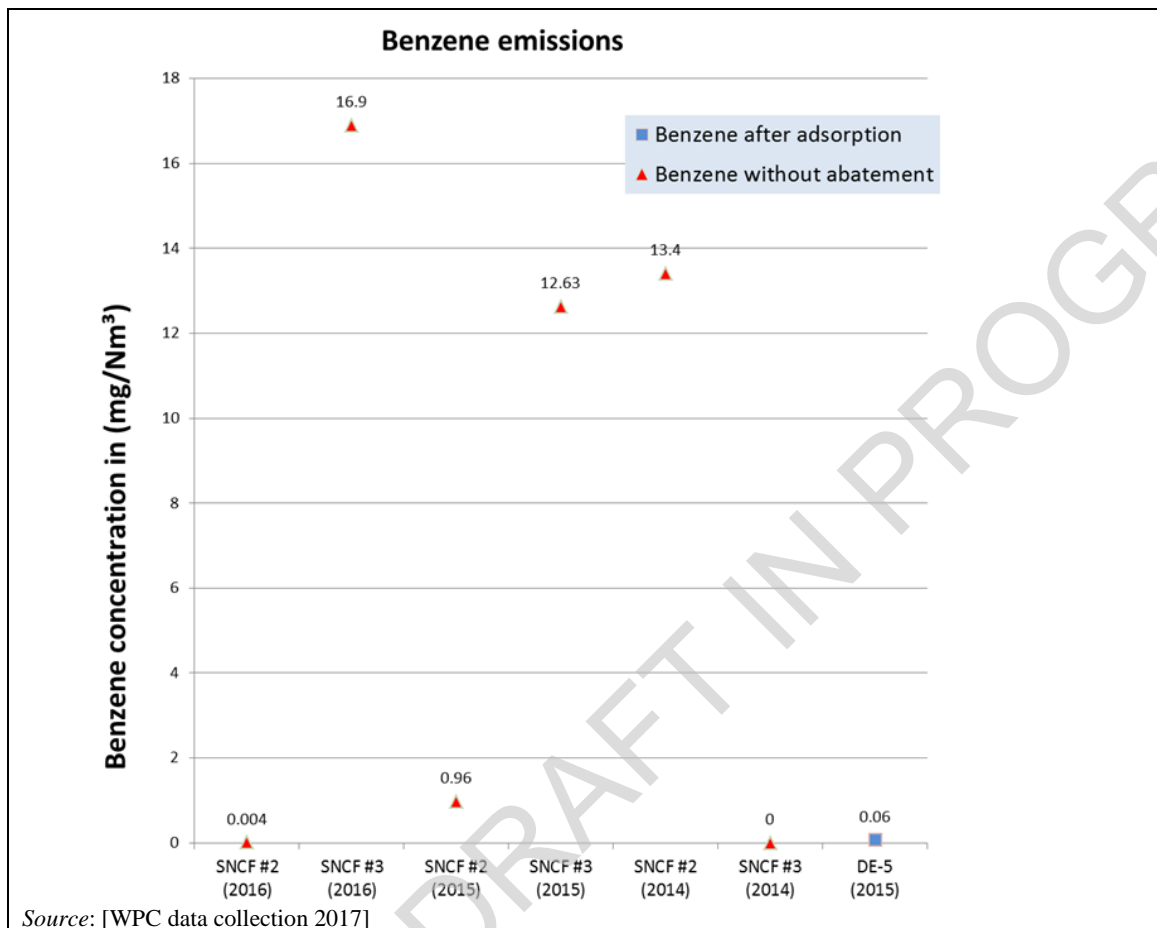
#### **(Other) CMR substances**

During the kick-off meeting, the TWG identified emission of CMR substances to air as a KEI for solvent-based (SB) and creosote plants. No information was submitted for SB plants.

CMR-VOC emissions were reported by one creosote plant (see above). *(Reported CMR-VOC values seem to be extremely high. EIPPCB asked for clarification whether the data might refer to VOC emissions; reply is pending.)*

Two creosote plants provided information on benzene emissions, see Figure 15.16. Values were  $0.06 \text{ mg/Nm}^3$  for the plant with air abatement system (adsorption) installed; and ranging from zero to  $16.9 \text{ mg/Nm}^3$  for the plant without abatement.

One plant also provide data on phenol emissions; the measured value in 2015 was  $<0.032 \text{ mg/Nm}^3$ .



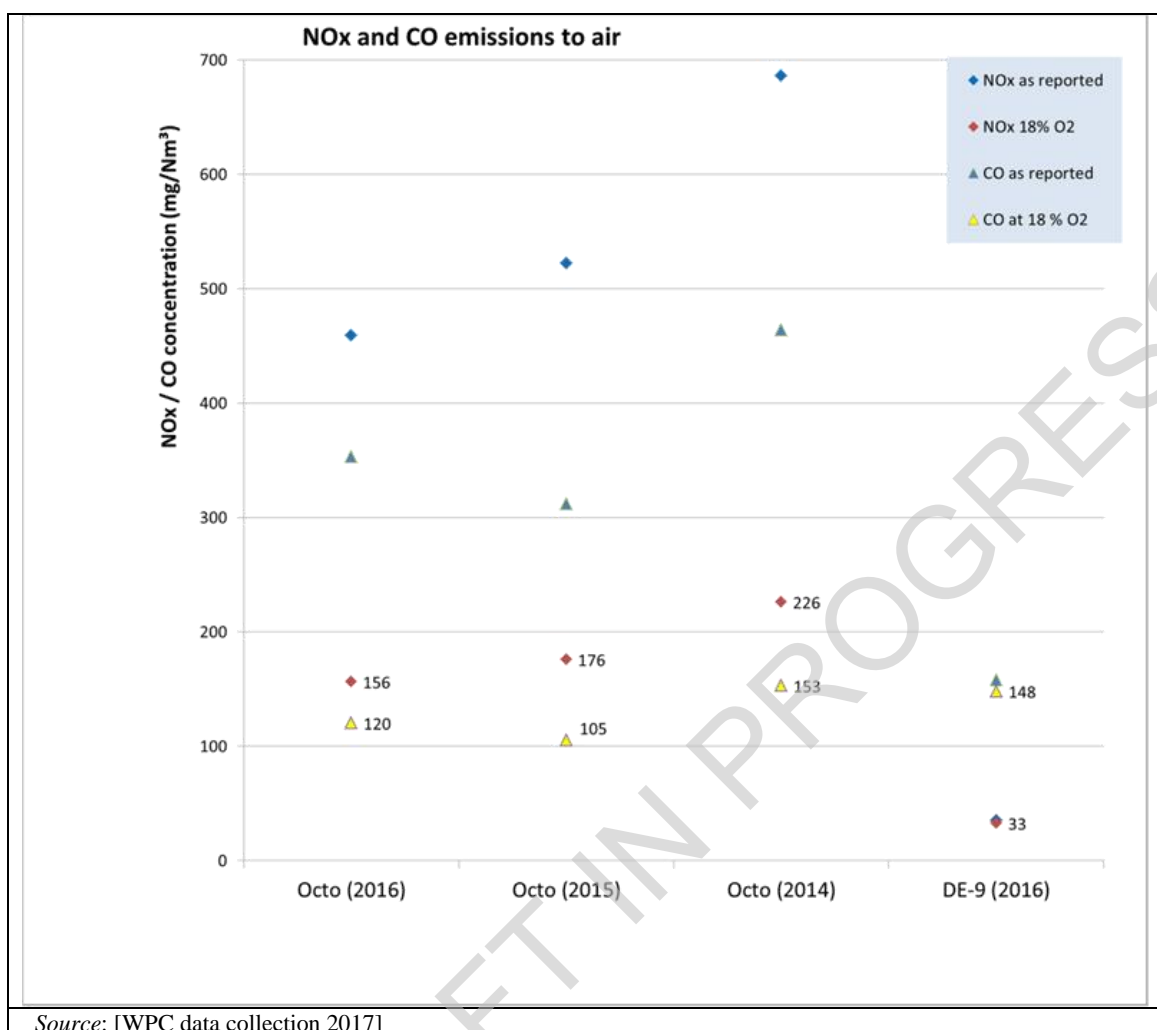
**Figure 15.16: Reported benzene emissions from creosote plants**

During the kick-off meeting, the TWG concluded to include in the information and data collection fugitive emissions of benzene. However, no information on fugitive emissions of benzene was submitted.

#### **NO<sub>x</sub> and CO emissions**

NO<sub>x</sub> and CO emissions are not emitted from the wood preservation process itself, but may be relevant for plants applying thermal oxidation or other combustion processes to reduce VOC emissions to air.

Two of the creosote plants that took part in the data collection with thermal oxidisers provided data on the NO<sub>x</sub> and CO emission values (see Figure 15.17). NO<sub>x</sub> emissions range from  $33 \text{ mg/Nm}^3$  to  $226 \text{ mg/Nm}^3$  at an O<sub>2</sub> level of 18 % with corresponding CO levels of  $148 \text{ mg/Nm}^3$  and  $153 \text{ mg/Nm}^3$ , respectively. Also lower CO values ( $105 \text{ mg/Nm}^3$  and  $120 \text{ mg/Nm}^3$ ) were reported.



Source: [WPC data collection 2017]

**Figure 15.17: Reported NO<sub>x</sub> and CO emission from creosote plants**

### Odour

During the kick-off meeting the TWG concluded that odour, together with emissions to air, is a KEI for plants with solvent-based preservatives and creosote treatment. However, no information was submitted on odour.

No information was submitted for solvent-based plants during the WPC 2017 data collection. *(TWG is kindly asked to provide data for SB plants to be included.)*

#### 15.3.3.4.2 Other emissions to air from wood preservation

##### Aerosols

Aerosol and vapour emissions to air from non-pressure and pressure processes (including treatment vessel, cylinder door, process tank, work tank vents, etc.) were identified at the kick-off meeting as a KEI for the WPC sector as a whole, but no data were submitted.

Some aerosols are generated during the final phases of the pressure treatment process, especially at the end of the final vacuum period and the return of the internal pressure in the treatment vessel back to atmospheric pressure. [OES auto 2016]

#### 15.3.3.5 Waste generation

Wastes arising from timber treatment plants may include:

- redundant preservative solution;
- sludge and debris from tanks;
- sawdust and other materials which have been used to soak up spills;
- redundant containers that still contain residues of the product;
- redundant plant and equipment (prior to decontamination);
- contaminated soil / dust / dirt.

The information on waste types and amounts generated which was provided during the WPC 2017 data collection is summarised in Table 15.21.

**Table 15.21: Reported waste types and amounts for wood preservation**

<i>Source: [WPC data collection 2017]</i>			

*Information from WPC 2017 data collection (questionnaires) to be added.*

WORKING DRAFT IN PROGRESS

## 15.4 Techniques to consider in the determination of BAT for wood preservation

The Sections 18.4 and 18.4.1 to 18.4.4 of the 2007 STS BREF have been replaced by the following Sections.

### 15.4.1 General/common techniques to consider in the determination of BAT for wood preservation activities

This section covers the techniques which are applicable to all or most preservative types, preservative application processes or process steps. The process (step)-specific techniques are covered in Section 15.4.2 and the preservative-specific techniques in Section 15.4.3.

#### 15.4.1.1 Environmental management systems (EMS)

##### 15.4.1.1.1 Environmental management systems (EMS)

*(updated standard text to be added plus WPC specific issues)*

#### Description

#### Technical description

Features of an Environmental Management System (EMS):

- i. commitment of the management, including senior management;
- ii. definition, by the management, of an environmental policy that includes the continuous improvement of the environmental performance of the installation;
- iii. planning and establishing the necessary objectives, targets and procedures, in conjunction with financial planning and investment;
- iv. implementation of procedures paying particular attention to:
  - (a) structure and responsibility;
  - (b) recruitment, training, awareness and competence at all levels;
  - (c) communication internally and externally;
  - (d) employee involvement;
  - (e) documentation;
  - (f) effective process control;
  - (g) maintenance programmes;
  - (h) emergency preparedness and response;
  - (i) safeguarding compliance with environmental legislation;
- v. checking performance and taking corrective action, paying particular attention to:
  - (a) monitoring and measurement (see also the JRC Reference Report on Monitoring of Emissions to Air and Water from IED Installations – ROM);
  - (b) corrective action;
  - (c) maintenance of records;
  - (d) independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained.
- vi. review, by senior management, of the EMS and its continuing suitability, adequacy and effectiveness;
- vii. following the development of cleaner technologies;
- viii. consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;

- ix. application of sectoral benchmarking on a regular basis.
- Identification and listing of all environmentally critical process and abatement equipment (whose failure could impact on the environment).
  - Written scheme of inspection and maintenance for the plant and equipment, including checks for integrity and correct functioning containment/bunds, safety locks, valves and alarms, tightness of valves and ductwork, check for visible drips/spillages.
  - Emergency plans for fire, accidental spills, etc.
  - Record of accidental leakages and spillages, and improvement plans (counter measures).
  - Consideration of decommissioning during design and operational phase including measures and provision of sufficient funds for site remediation.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

#### 15.4.1.2 Substitution of harmful / hazardous substances

##### 15.4.1.2.1 Chemical wood modification

###### **Description**

The chemical modification of wood is a biocide- and solvent-free process which induces a reaction between an introduced molecule and the wood polysaccharides, creating a permanent change throughout an entire section of wood. Current commercial processes include acetylation (full sapwood and heartwood impregnation with an acetic solution) and furfurylation (full sapwood and heartwood penetration with a solution of furfuryl alcohol derived from plant waste). [WPA October 2011]

###### **Technical description**

Chemical wood modification changes the chemical composition of the cell wall by reaction with chemical reagents. These are introduced into the wood - usually in aqueous form - by pressure impregnation. The chemical reaction is triggered by increasing the temperature (up to 140 °C). After removal of the excess impregnating agent (vacuum), the timber is dried to delivery or service moisture content. Chemical wood modification is always carried out in closed plants.

Chemical wood modification processes used on a commercial scale include acetylation, furfurylation and polymerisation. [VDI 3462 draft 2014]

###### Acetylation

The acetylation process uses acetic acid anhydride as a reagent to react with functional groups in the wood. During the modification process acetic acid is generated as a by-product which is treated and reused. The acetylated wood may contain residual reagent concentrations; occupational health and safety regulations have to be taken into account during further processing. [VDI 3462 draft 2014]

###### Furfurylation

The furfurylation process is similar to acetylation treatment except that it uses furfuryl alcohol as a reagent. [VDI 3462 draft 2014]

###### Polymerisation *(description to be added)*



**Achieved environmental benefits**

No use of biocides, creosote or solvents.

**Environmental performance and operational data**

Emissions including odorant emissions may be generated when opening the impregnation and reaction vessels, during transfer of the treated wood to the drying kilns and during drying. [VDI 3462 draft 2014]

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.1.2.2 Thermal wood modification****Description**

Thermal wood modification (TMW) is a biocide- and solvent-free process which induces a permanent change in the polysaccharides (e.g. starch and cellulose) of the wood to enhance its performance. Wood is heated to a temperature in excess of 160 °C in an environment in which oxygen is restricted or eliminated to achieve the desired performance characteristic without charring of the surface. [WPA October 2011]

**Technical description**

TMW is a process by which the composition of the cell wall material and its physical properties are modified by the exposure to temperatures higher than 160 °C and conditions of reduced oxygen availability. The wood is altered in such way that at least some of the wood properties are permanently affected through the cross section of the timber [CEN/TS 15679:2007]

Thermal wood modification is typically achieved by exposure of the wood to temperatures of 160 °C to 250 °C under reduced oxygen availability with the result of a permanent change in the wood's essential properties. Typical starting materials are dried roundwood and sawn timber, either softwood or hardwood. Wood modification is carried out in closed plants. There are several process variants that essentially produce similar effects, but differ in the way the oxygen reduction is accomplished and in the temperature, humidity and pressure conditions during the process. [VDI 3462 draft 2014]

Two example processes are described below:

***Thermal treatment based on the pressure impregnation technology***

This process requires no chemicals or inert gases. As such, it is a completely solvent-free process. This treatment is applicable to all types of wood (dry or fresh), and it is especially suitable for European wood. The thermally treated wood can be used for both outdoor (not for ground contact) and indoor applications. [Guidance 12 Wood impregnation 2007]

The process consists of steam treating the wood in an autoclave at a temperature of 140 - 210 °C and a pressure of 14 - 20 bar. The process modifies the cell structure of the wood, thus reducing its water absorption capacity. Additionally the dimension stability is improved and the wood becomes more durable. The wood is preserved throughout its cross section whereas in the case of impregnation, this can only be achieved for wood of small dimension. The process is already used at industrial scale but there is work on progress to improve product quality. It seems that the durability and preservation resulting from this process, if applied properly, are similar to creosote-impregnated wood. [Guidance 12 Wood impregnation 2007]

***Hydrothermal wood modification***

The process consists of five steps:

- Pre-drying stage.
- Hydro-thermolysis stage. The wood is heated to 150 - 180 °C in an aqueous environment. The cellulose remains intact, and the wood keeps therefore its good mechanical properties.
- Drying stage. The wood is reconditioned to a dry environment in a conventional industrial wood kiln.
- Curing stage. The wood is heated to 150 - 190 °C under dry conditions.
- Conditioning stage. The moisture content of the wood is elevated to a level which is necessary for manufacturing. [Guidance 12 Wood impregnation 2007]

Also liquid organic heat transfer fluids (e.g. rapeseed oil) have been reported to be used to provide the heat input for the thermal modification process. [VDI 3462 draft 2014]

**Achieved environmental benefits**

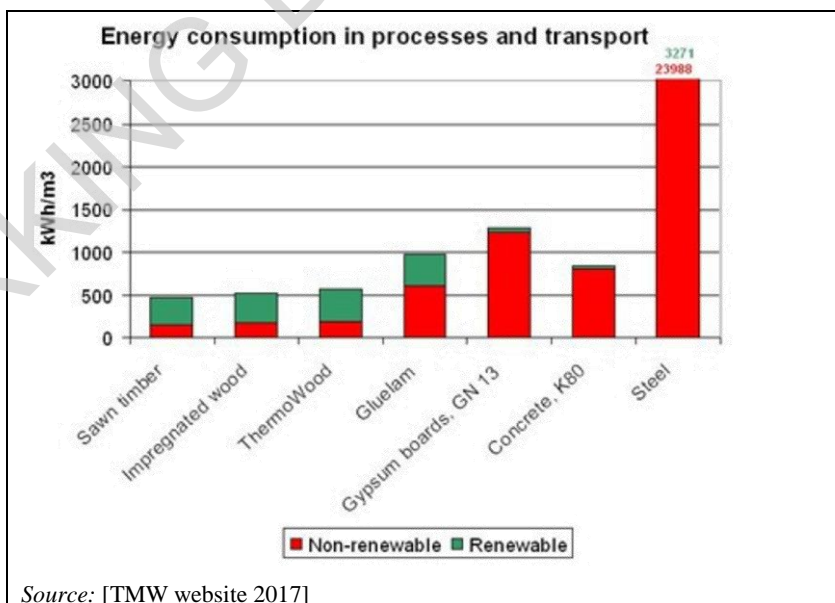
- No use of treatment chemicals (biocides, creosote, solvents).
- No emission of VOCs from creosote or solvents use.

**Environmental performance and operational data**

The average electric and thermal energy consumption for the thermal modification of 1 m<sup>3</sup> of wood ranges between 400 kWh and 550 kWh. [VDI 3462 draft 2014]

Thermal wood modification can be seen as partial pyrolysis of the wood. Exposure to elevated temperatures causes volatile organic compounds - part of which are odorous - to be driven off and results in the thermal modification of the wood components, mainly the hemicelluloses (wood sugar) but partly also the celluloses and lignin. The resulting decomposition products either remain in the wood or are emitted during or after treatment. Depending on the wood species, process and treatment intensity, the resulting mass loss is about 3 % to 5 %. [VDI 3462 draft 2014]

The thermal modification process generates gaseous and aerosol emissions. These consist in particular of terpenes, organic acids (e.g. acetic acid, formic acid) or aldehydes (e.g. furfural). The composition, concentration and physical state of the emissions are governed by the wood species, the process and the treatment intensity. Moreover, the process generates condensates. [VDI 3462 draft 2014]



**Figure 15.18: Comparison of specific energy consumption for impregnated wood and thermally modified wood**

**Cross-media effects**

Emissions to air and consumption of energy.

Energy consumption is increased due to the higher temperatures and longer treatment times compared with other treatments. [Guidance 12 Wood impregnation 2007]

**Technical considerations relevant to applicability**

Applicable to new plants or major upgrades of existing plants.

The heat treatment may also affect the product quality. It results in a loss of the wood's elasticity and solidity and, as a consequence, its mechanical strength. In addition, a darkening of the wood occurs. In some cases a change of shape may result from it. Finally, choice of the correct temperature curve for each wood requires skill and experience. [Guidance 12 Wood impregnation 2007]

**Economics**

The investment cost for thermal treatment installations is nearly double that of water-based systems. The process is generally more expensive than other preservation techniques; there is no cost of preservative but the process take two to five times longer. [Guidance 12 Wood impregnation 2007]

Investment costs for thermal treatment equipment are typically between EUR 500 000 and EUR 1 000 000 for a batch size of 50 m<sup>3</sup> or more, the operational costs are about EUR 50 – 100/m<sup>3</sup>. [Guidance 12 Wood impregnation 2007]

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.1.2.3 Supercritical carbon dioxide process****Description**

The supercritical carbon dioxide process is a pressure impregnation process in which supercritical CO<sub>2</sub> is used as carrier for the preservatives/active substances (instead of liquid organic solvents), thus resulting in a solvent-free process.

**Technical description**

The impregnation takes place in a closed processing facility with high recirculation of the excipients. The wood is placed in a treatment vessel - similar to those used in normal pressure treatment processes - and the wood preservative (treatment chemicals) is added. The pressure in the container is slowly increased by the addition of carbon dioxide. When the pressure exceeds 74 bar and a temperature of 31 °C, the carbon dioxide enters the supercritical state. In this state the CO<sub>2</sub> behaves as a fluid and serves as carrier for the preservatives. It carries the impregnating agent into the wood and the entire cross-section of the wood is impregnated. After a short time the pressure in the impregnating vessel is lowered to atmospheric pressure by extracting the carbon dioxide from the container and thus from the wood. The preservatives remain in the wood. The carbon dioxide is recirculated. [CO2 website 2017]

The preservative used consists of three organic fungicides: propiconazole, tebuconazole and IPBC and a binding agent, which binds the active substances and provides the wood with a water-repellent effect. [CO2 website 2017]

Afterwards, the impregnating the wood has the same moisture percentage and the same mechanical properties as before the treatment. The wood can be delivered and no additional fixation or drying is required before use. The wood produced by this process is suitable for all outdoor uses, e.g. for facade cladding. It should not be used in permanent contact with soil or water, and it may not be used in direct contact with food. [CO2 website 2017]

Like liquids, supercritical CO<sub>2</sub> has a high density, allowing for dissolution of biocides. However, supercritical CO<sub>2</sub> has no surface tension and the viscosity is closer to that of gases. Consequently, supercritical CO<sub>2</sub> penetrates wood more easily than liquid solvents, allowing for the impregnation of refractory wood species like spruce, which are difficult to impregnate using liquid solvents. Another feature which separates the supercritical impregnation process from conventional liquid impregnation techniques is that the process is a dry impregnation process. Being a gas, supercritical CO<sub>2</sub> does not wet the wood and the wood is dry before, during and after impregnation. Because the wood is dry after impregnation, quality control of chemical uptake cannot be checked by simply weighing the wood, but has to be carried out by chemical analysis. Supercritical CO<sub>2</sub> acts as a non-polar solvent and does not allow for impregnation of wood with metal ions such as copper or boron. The choice of available actives for supercritical wood impregnation is therefore limited to molecules that can be solubilised in supercritical CO<sub>2</sub>, typically organic molecules. [DK BAT cand CO2]

### **Achieved environmental benefits**

- No use of solvents or heavy metals.
- No waste water is generated.
- After the treatment process the wood is dry and no dripping will occur (reduced risk of soil and groundwater pollution). [DK BAT cand superwood]

### **Environmental performance and operational data**

In an acknowledgement of the potential environmental benefits, Superwood was awarded the European Award for the Environment in 2002. [DK BAT cand CO2]

### **Cross-media effects**

None known. [DK BAT cand CO2]

### **Technical considerations relevant to applicability**

Special design of plant is needed. [DK BAT cand CO2]

**Economics** No information submitted.

### **Driving force for implementation**

No use of solvents. No use of heavy metals. No dripping/fixation area needed. [DK BAT cand CO2]

### **Example plants**

Superwood A/S, Hampen, Denmark. [DK BAT cand CO2]

### **Reference literature**

1. SUPERWOOD process.PDF
2. <http://www.superwood.eu/benefits/from-wood-to-superwood/impraegnering>

#### **15.4.1.2.4 Substitution of solvent-containing preservatives by water-based preservatives**

##### **Description**

Solvents or creosote are replaced by water as a carrier for the biocides.

##### **Technical description**

Water-based low-pressure processes mainly substitute solvent-based preservative systems while water-based high-pressure processes are suitable to substitute creosote. Water-based treatments can be used instead of creosote for some end uses up to a 30-year life expectancy (and longer with case-by-case approval of the preservative manufacturer). Examples are medium-life

fencing, cladding of agricultural buildings, some horticultural uses. [Guidance 12 Wood impregnation 2007]

Water-based preservatives can also be used in open impregnation systems, e.g. in dipping installations. [Guidance 12 Wood impregnation 2007]

#### **Achieved environmental benefits**

- No use of creosote or solvents.
- Emissions of solvents (i.e. VOCs) are avoided.

#### **Environmental performance and operational data**

Switching from solvent-based preservatives to water-based systems can achieve a VOC reduction approaching 100 %, or, for water-based micro emulsion systems, a reduction of 99 %. [Guidance 12 Wood impregnation 2007]

Refer also to consumption and emission levels presented for water-based preservatives in Section 15.3.

**Cross-media effects** No information submitted.

#### **Technical considerations relevant to applicability**

- Applicable to plants using solvent-based preservatives or creosote.
- In some cases the quality requirements of the wood/wood product may not be achievable by water-based preservatives, e.g. due to the swelling of the wood, which must be avoided when treating certain finished products.
- In addition, timber treatments with higher levels of copper (ACQ and CuAz) are more corrosive. [Guidance 12 Wood impregnation 2007]

#### **Economics**

The process of impregnation of solvent-based and water-based preservatives is very similar with no significant economic differences.

In a typical new installation wood is treated in a 18 m<sup>3</sup> reactor with a charge capacity of 14 m<sup>3</sup> wood. The impregnation cycle takes 4 hours and can therefore be repeated 6 times a day due to a 24-hour shift work. With 250 working days a yearly production of about 20 000 m<sup>3</sup> can be achieved. Depending on the intended application the raw material costs are between EUR 10 and EUR 30/m<sup>3</sup>, energy costs are negligible and water costs are EUR 0.5–1.5/m<sup>3</sup>. The investment costs for this plant are about EUR 250 000. Depending on the preservative type, the impregnation costs can vary between EUR 20 and EUR 40/m<sup>3</sup>. [Guidance 12 Wood impregnation 2007]

**Driving force for implementation** No information submitted.

#### **Example plants**

Plants applying BAT candidate: DE-6 (DE), ISB (FR), Margaritelli (IT), Lonza (UK), Windymains (UK) [WPC data collection 2017]

**Reference literature** No information submitted.

#### **15.4.1.2.5 Substitution of potentially harmful preservatives / treatment chemicals by less hazardous preservatives / treatment chemicals**

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Description** No information submitted.

**Technical description** No information submitted.

#### **Achieved environmental benefits**

Less direct impact from chemicals used in case of emissions, less hazardous waste.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**

For poles only according to sector's standard requirements and to customer requests. [Q Stella 2017]

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-6, DE-9, Paras, ISB, SNCF, Oriel, PivB, Marga, Stella, Bitus, Varberg, Lonza, WindyM,

**Reference literature** No information submitted.

**15.4.1.3 Soil, water and groundwater protection and material management**

**15.4.1.3.1 Appropriate plant design and layout**

**Description**

**Technical description**

- a) floor in the plant sloping towards a well or spill storage tank
- b) roofed treatment area
- c) level, impervious, paved traffic ways in delivery area
- d) technically tight pumps, flanged joints, valves and feeders

**Achieved environmental benefits**

Reduction of emissions to soil, water and groundwater.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**

Some design features, e.g. when affecting the floor/foundation underneath the plant, are best considered during design stage of a plant; retrofitting existing plants requires interruption of production and space availability.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.1.3.2 Plant and equipment containment or bund**

**Description**

The parts of the plant that store or handle treatment chemicals or solvents, i.e. solvents and treatment chemicals storage area, treatment area (comprising treatment vessel, working vessel, unloading/pull out facilities, dripping/drying, cooling zone), pipes and ductwork for solvents and/or treatment chemicals, creosote (re)conditioning facilities are contained or banded. Containments and bunds are sealed, with impermeable surfaces, resistant to wood preservatives and with sufficient capacity to capture and hold the wood preservative volumes handled or

stored in the plant/in the contained equipment. Containments/bunds are inspected and maintained regularly.

### Technical description

Containments or bunds are designed to contain (larger amounts) of wood preservatives (chemicals) in the event of unpredicted leakage, rupture or failure of tanks, accidental spills etc. The containment/bund should fulfil the following design features:

- capacity to retain all preservative fluid (chemicals) in case of leakage or accident;
- impervious and resistant to the chemicals (preservative used);
- able to withstand static pressure of liquids (volume) to be captured.

One source suggested that the bund for plants with a single storage tank should be constructed with a capacity of at least 110 % of the preservative (chemical) storage capacity. For multiple tanks in the same containment or bund it should be 110 % of capacity of the largest tank or 25 % of the total volume that could be stored in all tanks in the containment/bund - whichever is greater. In other scenarios (e.g. storage of preservative in drums) it should be at least 25 % of the total volume that could be stored at any time. [EWPM\_WEI tech info 1-2016]

The containment area or bund can - depending on site layout - incorporate the whole plant or consists of separate dedicated containments for parts of the WPC plant, e.g. containment of wood preservative delivery, storage and mixing area, of treatment vessel(s) and associated loading/unloading areas, the treatment area. Examples of potential designs are given in Figure 15.20, Figure 15.21 and Figure 15.22 below.

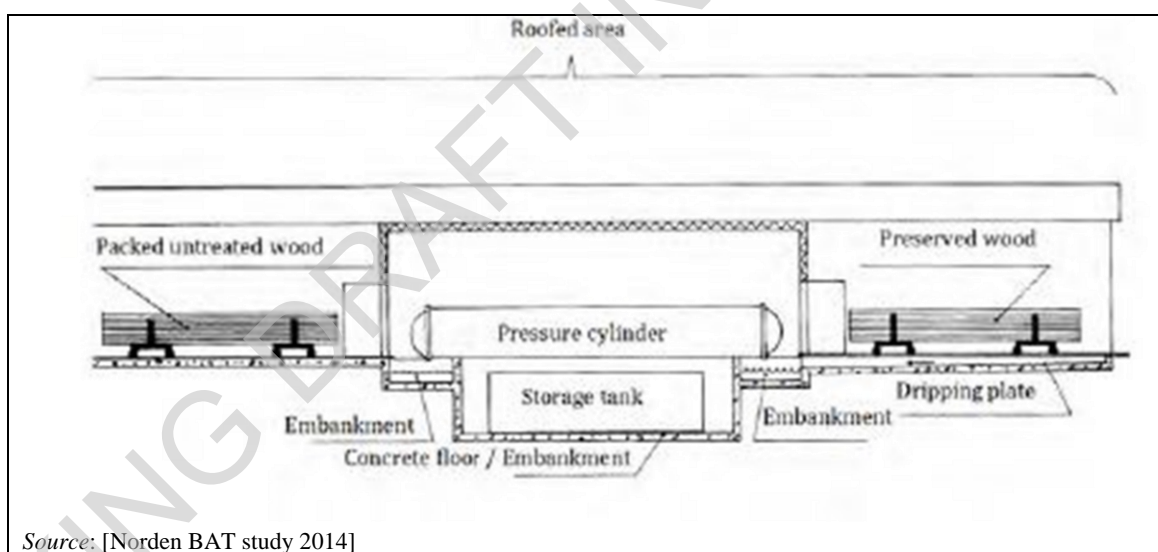
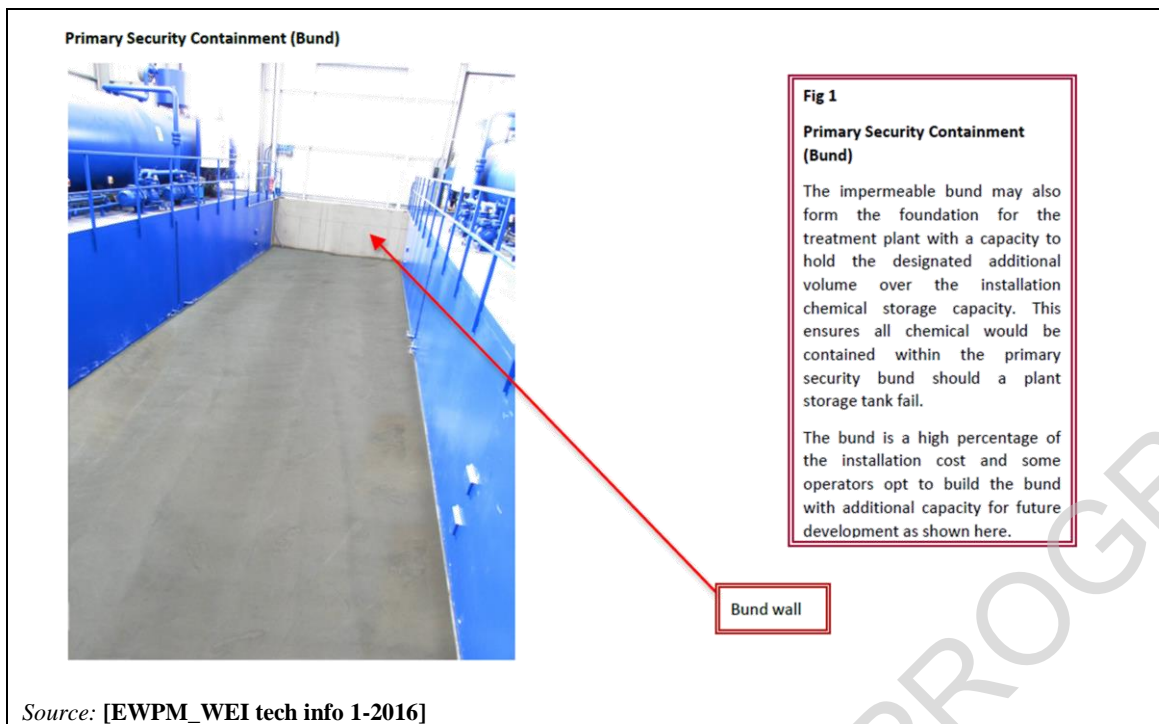


Figure 15.19: Schematic showing various options of precautionary measures (containment, drip pads, roof covers)



**Figure 15.20: Design examples for process containment**



**Figure 15.21: Design examples for process containment**

**Technical considerations relevant to applicability**

- Applicable to new plants or major upgrades of existing plants.
- Retrofitting existing plants requires activity interruption and space availability near and under the treatment lines. The incompatibility with wood handling systems may limit the application to loading/unloading areas in the case of handling machines (instead of automatic systems) as the containment may limit the access of handling machines to loading/unloading areas. [Q Stella 2017]

**Economics** No information submitted.

**Driving force for implementation**

Soil and groundwater protection



**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.1.3.3 Use of empty underground tanks/wells to retain leakage

*(Technique was proposed as BAT candidate by an IT plant, but no information was provided. If the TWG considers this technique a BAT candidate to be considered in the determination of BAT, the TWG is kindly asked to provide the relevant information for this technique.)*

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.1.3.4 Use of mobile absorbent systems

*(Technique was proposed as BAT candidate by an IT plant, but no information was provided. If the TWG considers this technique a BAT candidate to be considered in the determination of BAT, the TWG is kindly asked to provide the relevant information for this technique.)*

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

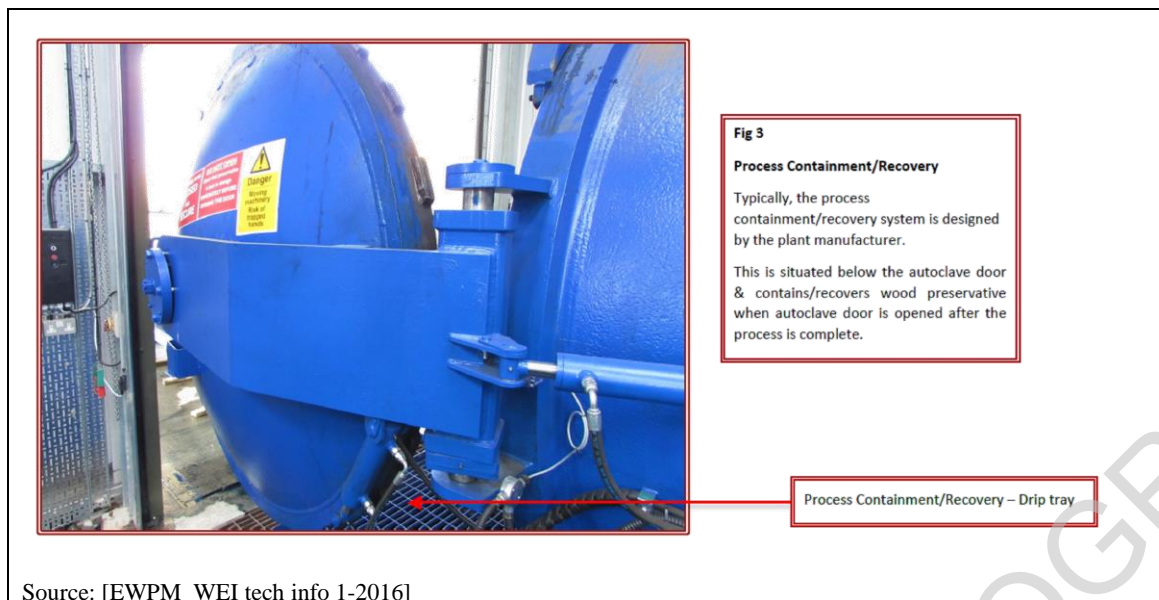
#### 15.4.1.3.5 Drip trays

##### **Description**

Collection device made of preservative-resistant material for collecting and recovering drips and spills of treatment chemicals placed under equipment or processes where drips may occur (i.e. valves, inlets/outlets of storage tanks, treatment vessels, working tanks, unloading/pull-out zones, handling of freshly treated wood, cooling/drying zone). The collected preservative solution is recirculated into the treatment chemicals system.

##### **Technical description**

To collect and recover wood preservatives (chemicals) from process steps where dripping may occur (e.g. when opening the autoclaves, unloading the treatment vessel (pressure and non-pressure), or from freshly treated wood after transfer from the treatment vessel loading system), drip trays are installed (also referred to as drip pans, drip pads or collecting trays). Unlike containments and bunds, drip trays are smaller and designed to collect drips and spillages, rather than total tank volumes, and during normal operation. Examples for potential drip tray configurations are shown in Figure 15.22 and Figure 15.23.



Source: [EWPM\_WEI tech info 1-2016]

Figure 15.22: Example of a drip tray underneath autoclave door



Source: [EWPM\_WEI tech info 1-2016]

Figure 15.23: Example of a drip tray incorporated into the unloading system (beneath pull out)

<b>Achieved environmental benefits</b>	No information submitted.
<b>Environmental performance and operational data</b>	No information submitted.
<b>Cross-media effects</b>	No information submitted.
<b>Technical considerations relevant to applicability</b>	No information submitted.
<b>Economics</b>	No information submitted.
<b>Driving force for implementation</b>	No information submitted.
<b>Example plants</b>	No information submitted.
<b>Reference literature</b>	No information submitted.

**15.4.1.3.6 Soil/floor sealing, spill and surface run-off collection with reuse**  
*(Text as provided, editing will be done at a later stage)*

**Description**

Sealed hardcover surface for areas where drippage, spills or accidental releases of preservatives/treatment chemicals or solvents may occur. Spills and/or surface run-off water is collected and used/reused in the preservative system.

**Technical description**

The floor in the areas where drippage, spills or accidental releases of preservatives/treatment chemicals or solvents may occur is sealed, spills and/or surface run-off water is collected and used/reused in the preservative system.

Information on several examples was provided and is described in more detail below.

**Example 1 (DE-1, mixed plant with WB and C treatment)**

The floor in the area of extraction rails of the installation is extensively sealed (1 500 m<sup>2</sup>). The rainwater from the sealed area of extraction rails is collected in a 50 m<sup>3</sup> cistern over an oil-sludge collector and used as process water. The oil sludge collector is cleaned regularly and accumulated waste is disposed of properly (ASN 130899 \*; variable quantities depending on waste formation). If the capacity of the cistern is not enough there is the possibility of storing rainwater in a wagon. If the cistern is full in the case of heavy rain events, the surface water in the cistern is directed into the drainage channel.

The floor sealing consists of a double bottom plate of water-impervious concrete. The detention reservoir is made of water-impervious concrete. [DE BAT study 2013]

**Example 2 (DE-2, WB plant)**

The extraction rail area and storage area for fresh treated wood is sealed (approximately 2.500 m<sup>2</sup>) and supplied with an inlet channel. Dripping water flows either into a drip tray or into the inlet channel. The dripping water from the inlet channel is conducted over the drainage channel, oil-sludge collector and pipes and lines to a collecting tray (50 m<sup>3</sup>) and returned back to the process.

The floor sealing consists of water-impervious concrete with an upper and lower steel mesh (thickness approximately 20 cm).

The sealed surface is covered and protected on the sides from rain (a new roof is under construction). The extraction rail area and the storage surface is sloped to allow flowing liquids to drain into the drip tray or inlet channel and from there pass over the oil-sludge collector, pipes and lines into the collecting tray (50 m<sup>3</sup>). The oil-sludge collector is regularly cleaned and accumulated waste disposed of accordingly (about 750 kg/year).

The collecting container is a double-walled underground tank coated with epoxy resin coating resistant to impregnating solution. The pump placed in the container is controlled over one float indicator, and, when it reaches certain level, the collected liquid is pumped back into the impregnation installation. The acoustic warning signals the pump malfunction. [DE BAT study 2013]

**Example 3 (DE-3, WB plant)**

The transport roads on the premises are flat and fixed. The floor in the area of the extraction rails is extensively sealed. The seal consists of the following layers:

- ≥ 3 cm of asphalt concrete;
- ≥ 15 cm bituminous base;
- 20–30 cm gravel base (partly available).

The dripping water and rainwater is led via the drainage channel to the collection bunker and used as process water (approximately 2.5 % inclination). If necessary, the water (along with roof run-off water) can be intermediately stored in designated tanks. Beside the roof run-off water and the water collected from the sealed area, no additional process water is used in the installation.

The collecting bunker made of water-resistant concrete serves as a buffer. The return of the water to the impregnating process is done automatically (automatic return at a certain water

level in the collecting bunker by means of a float indicator and submerge pump (1.85 kW).) [DE BAT study 2013]

### **Example 4 (DE-4, WB plant)**

The entire floor area of the installation's workspace is paved (approximately 40 m<sup>2</sup>). The draining water runs back into the trough.

Floor sealing is made of concrete. The concrete surface is also covered and protected on the sides against rain. The extraction rail area and the area for draining are inclined to facilitate back flow of discharged liquids in the drip tray. [DE BAT study 2013]

### **Achieved environmental benefits**

- Prevention of soil contamination by preservatives (drippings).
- Reduction of fresh water consumption when reusing collected water.
- Reduction of waste water volume. [DE BAT study 2013]

### **Environmental performance and operational data**

The technique must be maintained (cleaning of oil- and sludge trap and disposal of the waste) regularly and is checked regularly (e.g. every five years) by an approved certifying body. Before each technical inspection, the collecting container needs to be emptied and cleaned. [DE BAT study 2013]

Plant DE-3 indicated that the collected water is even more suitable for the impregnation process than the well water (due to the high proportion of precipitation water, which is essentially demineralised water). The well water has a lower pH value of 6.14 and a moderate nitrate pollution of 19.9 mg/l. It can be described as 'metallic'. The pH value of the wood-preserving salt solution is 10.2 to 10.4. The indicated amount of water is equivalent to the specified range.

Water savings of approximately 570 m<sup>3</sup> for impregnation were reported (DE-1).

Rainwater falling on the sealed surfaces and on the roof can be used as process water. In the case of plants DE-1 and DE-3, large areas of the sealed surfaces are not covered with a roof. This can save significant amounts of fresh water (DE-1: 570 m<sup>3</sup>; DE-3: 2 550 m<sup>3</sup>). [DE BAT study 2013]

### **Cross-media effects**

In principle, any soil sealing / surface sealing has a negative effect on the natural hydrological structure, since precipitation can no longer penetrate the soil. However, in the examples described above, the environmental benefits of preventing soil contamination prevail. [DE BAT study 2013]

### **Technical considerations relevant to applicability**

- Applicable to new and existing plants.
- In some cases of WB plants in which process control is based on conductivity monitoring of chemical solution, reuse of water (particularly rainwater) is difficult, because it changes the conductivity range of the solution too much, so that process control is not efficient. [Q Stella 2017]
- Plants where no water-based preservatives are used there is no need for process water (no potential for reuse). The effluents then need to be treated, e.g. in a waste water treatment, or be properly disposed of as liquid waste (refer to . [DE BAT study 2013]

### **Economics**

- Avoidance of costs for the elimination of environmental damage. [DE BAT study 2013]
- Reduced costs for water and waste water treatment.

### **Plant DE-1:**

Cost savings for impregnation due to water saving of approximately 570 m<sup>3</sup> per year.

**Plant DE-2:**

- Costs for soil sealing/collecting bunker: estimated at around EUR 800/m<sup>2</sup>.
- Approximate annual operating and maintenance costs (personnel, spare parts, certification, etc.): every five years about EUR 6 000 (EUR 3 000 for technical certification by approved certifying bodies; the same amount to prepare for testing).

**Plant DE-3:**

- Investment costs for soil sealing and collecting bunker: EUR 85/m<sup>2</sup> in 1998 (including sand blasting); approximately EUR 24 000 for the collecting bunker with 125 pressure piping (production costs in 1998).
- Approximate annual operating and maintenance costs (personnel, spare parts, certification, etc.): EUR 8 000/year.
- Annual cost savings by reducing water consumption (2 550 m<sup>3</sup>/yr): the self-provision of water through the installation's well is up on the annual water analysis free of charge. This allowance is exceeded by an additional use of water for the impregnation and additional water abstraction charge (2011: 4.5 ct/m<sup>3</sup>) would have to be paid for the process water.

**Plant DE-4:** no data available.

**Driving force for implementation**

- Regulatory requirements (operating permit).
- Prevention of soil and water contamination.
- Water saving and better water quality for the impregnation process.
- Reduction of operating costs.
- Independence from fresh water sources [DE BAT study 2013]

**Example plants** DE-1, DE-2, DE-3, DE-4

**Reference literature** No information submitted.

#### 15.4.1.3.7 Pressure-reducing valves for high-pressure pipes connected to mixing tanks

*(Technique proposed as BAT by Nordic council in [Norden BAT study 2014], but no information (10 heading structure for BAT candidates) provided.)*

Measure to prevent/reduce leakages of chemicals to the environment [Norden BAT study 2014]

**Description** No information submitted.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-5, DE-9, DE-8, Paras, Bitus, C&G,

**Reference literature** No information submitted.

**15.4.1.3.8 Alarms/warning systems for equipment identified as 'critical'****Description**

'Critical' equipment is equipped with alarms/warning systems to indicate malfunctions or breakdown. These alarm/warning systems are maintained and checked regularly to ensure continued correct operation.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.1.3.9 Use of an efficient preservative application system**

*(Technique was included as BAT in STS BREF 2007, during the revision no information on benefits and/or plants applying this technique was provided).*

**Description**

Application systems where the wood is immersed in the preservative solution have a higher efficiency than, for example, spraying. The application efficiency of vacuum processes (closed system) is close to 100 %.

**Technical description**

Different preservative application systems vary in their application efficiency (i.e. the amount of preservative used to achieve certain retention in the wood; how much of the preservative solution actually affects the wood during the treatment procedure). Application system where the wood is immersed in the preservative solution have a higher efficiency than, for example, spraying. The application efficiency for dipping and brushing is close to 90 %, and using the vacuum process with full containment is close to 100 %. Spraying has a much lower efficiency, i.e. from 10 % to 50 %.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.1.3.10 Control and optimised consumption of treatment chemicals for the described end use of the wood/wood product****Description**

Control of consumption of treatment chemicals by: a) weighing of the wood/wood product before and after impregnation or b) calculation and verification of the impregnation rate during and after impregnation (requiring measurement of liquid levels in vessels and tanks) and not exceeding retention rates required by product quality standards or suppliers recommendations.

**Technical description**

Consumption of treatment chemicals is controlled through a) weighing of the wood/wood product (e.g. poles) before and after impregnation or through b) calculation and verification of the impregnation rate during and after impregnation (which requires measurement of liquid levels in vessels and tanks). [Q Stella 2017]

The amount of treatment chemical introduced in the wood should be within the range required by product quality standards (e.g. use class, penetration class) and the retention amount for treatment chemicals as proposed by supplier.

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

#### **Example plants**

Plants applying BAT candidate: DE-6, DE-5, DE-9, DE-8, Paras, ISB, PivB, Marga, Stella, Track, Bitus, Varberg, C&G, Sodra, WindyM

**Reference literature** No information submitted.

#### **15.4.1.3.11 Solvent mass balance**

Refer to **17.3.1** Mass balances for solvents in STS part

#### **Description.**

The compilation, at least on an annual basis, of the organic solvent inputs and outputs of a plant as defined in Part 7 of Annex VII to Directive 2010/75/EU.

**Technical description** No WPC specific information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### **15.4.1.4 Organisational and operational techniques to improving the environmental performance of WPC plants**

##### **15.4.1.4.1 Regular inspection and maintenance of plant and equipment**

#### **Description**

The plant and equipment are regularly inspected and serviced to ensure proper functioning; this includes especially the check of the integrity and/or leak-free status of valves, pumps, pipes, tanks, pressure vessels, drip trays, containment facilities and bunds and the functionality of alarms/warning systems.

#### **Technical description**

Regular inspection and maintenance of the installation and equipment are fully integrated in a plant's quality management system. A number of aspects of the plant design, installation and operation are subject to the need for regular inspection and maintenance. [OES auto 2016]

Key aspects include:

- the integrity of the (dipping) tank or the pressure vessel;
- the electrical safety of the plant equipment;
- the leak-free status of valves and pipes;
- ensuring the capacity of the bund and foundations are not compromised and are adequate in the event of a catastrophic loss of preservative from the treatment vessel or storage tanks into the bund area;
- the integrity of the door seal (for autoclaves);
- visual examination of the tightness of the retention tank;
- regular checks of the tightness of pressure tanks;
- a planned written scheme of maintenance;
- records of the maintenance and inspections of all routine maintenance, periodic servicing, examinations and remedial work. [OES auto 2016]

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.1.4.2 Baseline report / measures related to de-commissioning

##### **Description**

Report on the state of soil and groundwater contamination by relevant hazardous substances.

##### **Technical description**

Refer to 'European Commission Guidance concerning baseline reports under Article 22(2) of Directive 2010/75/EU on industrial emissions (2014/C 136/03)'.

##### **Example plant Track (mixed WB & C):**

A baseline report was prepared in 2015 containing information on current and past land use. The treatment wood started already in 1938. The historical pollution of soils and groundwater identified on site, was caused by improper storage of creosote oil. The main pollutants are mineral oil, toluene, acenaphtalene and naphthalene.

##### **Example plant Lonza (WB):**

In 2015 a desk study and site investigation were carried out in order to address any potential geoenvironmental concerns in the context of the requirements of Section 2 of a Site Condition Report, required for the new type of environmental permit under the IED. The scope of work comprised the following:

- Preliminary desktop study research in accordance with CLR11 (Model Procedures for Management of Land Contamination), including a site walkover;
- Intrusive investigation, sampling and laboratory testing;
- Ground gas and groundwater monitoring and groundwater sampling (if present);
- Assessment of contamination / ground gas conditions on site.

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.

##### **Technical considerations relevant to applicability**

New and existing plants.

**Economics** No information submitted.



**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-5, ISB, PivB, C&G, Lonza, Froslev, Track, SNCF, Marga, Sodra, WindyM

**Reference literature** No information submitted.

**15.4.1.4.3 Measures facilitating decommissioning**

**Description**

Examples of potential measures:

- Consideration of decommissioning during design and operational phase including provision of sufficient funds for site remediation.
- Avoiding underground storage and ductwork.
- Recording underground facilities and maintaining a record of incidents that may cause soil and/or groundwater pollution.
- Decommissioning plan.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.1.4.4 Dedicated transport vehicles for potentially contaminated areas**

**Description**

Vehicles used to transport the wood/wood products in potentially contaminated areas (e.g. treatment areas) are confined to these areas and are not used in other, non-contaminated areas of the plant.

**Technical description**

In cases where wood/wood products are transported by vehicles (forklifts etc.) these vehicles will eventually become contaminated with treatment solution. Dedicated vehicles are used to transport the wood/wood products in potentially contaminated areas (e.g. treatment areas). These are retained in the wood treatment area in order not to carry over any preservative solutions to uncontaminated areas. Before removing the vehicles, e.g. for maintenance, they have to be washed down with clean water. The cleaning water is added to the treatment system. [UK SG11 draft 2013]

**Achieved environmental benefits**

Limitation of soil contamination to confined areas.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Stella S.P.A. ad Unico Socio (IT)

**Reference literature** No information submitted.

#### 15.4.1.4.5 Crane system for handling wood

##### **Description**

In place of a dedicated transport vehicle, an overhead crane system is used to transport wood packs to and from treatment, drying and dispatch. [Q Windymains]

##### **Technical description**

This technique is an overhead crane system operating across the full roof area of the treatment shed. The crane is operated from a roof gondolier operations room which ensures that staff are not in the working areas. [Q Windymains]

The lift system allows for greater densities of wood packs and allows full use of the treatment shed as drive routes are not required and pedestrian access is limited to 'safe areas'. Greater numbers of wood packs reduce the area of shed required for post-treatment drying with the associated reduction in resource. [Q Windymains]

Roof-mounted crane systems are universally used in the handling of heavy loads within many industries. The use of this technology within the WPC sector in the UK is unusual due to a traditional reliance on vehicles; however, with a shift in focus to the prevention of 'chemical drag-out' by vehicles, these systems could become ubiquitous. [Q Windymains]

##### **Achieved environmental benefits**

Limitation of soil contamination to confined areas.

Use of electrical energy replacing the use of fossil fuels used to power a vehicle. Reduction in release of emissions from vehicles and reduced on-site storage of fuels and the potential associated impact. [Q Windymains]

##### **Environmental performance and operational data**

Data are not available to identify the energy requirements of this system due to limited submetering on use on site. [Q Windymains]

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

##### **Economics**

Cost differences between vehicle purchase and operation against crane system costs are unknown. [Q Windymains]

##### **Driving force for implementation**

Increased density of wood handled within a treatment shed. Safety of personnel due to elimination of vehicle movements and need to operate close to treatment chemicals. [Q Windymains]

##### **Example plants**

Windymains Timber Ltd (UK).

**Reference literature** No information submitted.

#### 15.4.1.4.6 Restricted access to potentially contaminated/contaminated areas and/or provision of grit walkways

##### Description

Stopping personal from walking through areas where dripping may occur and/or providing grit walkways (no contact of footwear with spills) avoids treatment chemicals/contamination being carried to non-contaminated areas.

##### Technical description

Stopping personal from walking through areas where dripping may occur and/or providing grit walkways (no contact of footwear with spills) avoids treatment chemicals/contamination being carried to non-contaminated areas.

##### Achieved environmental benefits

Limitation of soil contamination to confined areas.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

#### 15.4.1.4.7 Wood pack management (trace) system

##### Description

A wood pack management (trace) system allows the audit of pack movements: recording when packs are processed; removed from the vessel and placed within the process area to allow dripping. It is used to prevent packs being moved off the impervious contained and drained area while they may still release preservatives. [UK SG11 draft 2013]

##### Technical description

The reasons for using trace systems are twofold:

- To monitor the production process and stack management. This may be part of a quality management system.
- To check on specific time constraints or characteristics of the timber which form part of the production process, for example the post-treatment conditioning period. [UK SG11 draft 2013]

The wood packs are usually traced by tags. The parameters and the characteristics of the treatment are monitored. [OES auto 2016]

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

### 15.4.1.5 Waste minimisation, management and on-site treatment

#### 15.4.1.5.1 Recirculation of collected drippage and spills of preservatives/treatment chemicals

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

##### **Description**

Drippage and spills of preservatives/treatment chemicals collected from drip pads or sealed surfaces are recirculated to the preservatives/treatment chemicals system.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

##### **Example plants**

Plants applying BAT candidate: DE-6, DE-7, DE-9, DE-8, Froslev, Paras, ISB, Oriel, PivB, Marga, Stella, Track, Bitus, Varberg, Lonza, Sodra, WindyM,

**Reference literature** No information submitted.

#### 15.4.1.5.2 Delivery of treatment chemicals or solvents in reusable containers

##### **Description**

Containers (IBCs) are returned to the supplier for reuse.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

#### 15.4.1.5.3 Cleaning of redundant preservative containers

##### **Description**

Containers that still contain residues of the preservatives are rinsed and cleaned. The cleaning water is reused for preparation of water-based preservative/treatment chemicals solutions.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.1.5.4 Separation of hazardous and non-hazardous waste at source and separate storage**

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-5, DE-9, DE-8, Paras, ISB, SNCF, Marga, Stella, Track, Varberg, C&G, Lonza, Sodra, WindyM

**Reference literature** No information submitted.

**15.4.1.5.5 Reuse, recycling and recovery of wastes**

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: Froslev, CO2, Paras, SNCF, Marga, Stella, Track, Varberg, C&G, Sodra, WindyM,

**Reference literature** No information submitted.

**15.4.1.5.6 Collection of preservative-treated wood waste for proper recovery or disposal as hazardous waste**

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-5, DE-9, DE-8, Froslev, Paras, ISB, SNCF, Stella, Track, Bitus, Varberg, C&G, Lonza, Sodra, WindyM

**Reference literature** No information submitted.

**15.4.1.5.7 Collection of preservative residues and sludges for proper disposal as hazardous waste**

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Description** No information submitted.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-6, DE-5, DE-8, Paras, ISB, SNCF, Marga, Stella, Track, Bitus, Varberg, C&G, Lonza, Sodra, WindyM

**Reference literature** No information submitted.

**15.4.1.5.8 Designated weather-protected area for storage of hazardous wastes**

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Description**

Bunded storage area for hazardous waste protected from surface run-off water and protected from rain (roofing).

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-6, DE-5, DE-9, DE-8, CO2, Paras, ISB, SNCF, Marga, Stella, Track, Bitus, Varberg, C&G, Lonza, Sodra, WindyM

**Reference literature** No information submitted.

**15.4.1.6 Water / Waste water management**

**15.4.1.6.1 Separation of clean, uncontaminated rainwater or surface run-off water**

**Description**

Clean, uncontaminated rainwater or surface run-off water is diverted away from the plant and/or equipment by drainage channels, outer kerb bunds and roofing with guttering.

**Technical description**

Keeping clean, uncontaminated rainwater or surface run-off water out of touch with preservatives and/or preservative-contaminated areas of the plant is achieved by channelling or

diverting it away from the plant or any equipment. This can be achieved by the following techniques:

- a) **Drainage channel:**  
A drainage channel around the whole plant stops rain and surface run-off water from entering plant areas and thus from being polluted.
- b) **Outer kerb bund:**  
An elevated rim around the whole plant or parts of the plant stops rain and surface run-off water from entering plant areas and thus from being polluted.
- c) **Roofing with roof guttering:**  
A roof protects the preservative and chemicals storage area, the treatment area and/or the post-treatment from rainwater. The run-off water from the roofs is collected by roof guttering and channelled away from potential sources of contamination.

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.1.6.2 Regular inspection, emptying and cleaning of oil separators, canals and sumps

##### **Description**

An inspection and maintenance programme can be put into place to prevent pollution by minimising leaks from subsurface pipework, sumps, canals and oil separators present in the installation.

**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

##### **Example plants**

Plants applying BAT candidate: DE-6, DE-5, DE-9, DE-8, ISB, SNCF, Marga, Track, Bitus, C&G

**Reference literature** No information submitted.

#### 15.4.1.6.3 Treatment of waste water/collected potentially contaminated rainwater and surface run-off

##### **Description**

Water (rainwater, surface run-off etc.) from sealed surfaces that is collected and cannot be reused in the wood preservation process is treated (before discharge).

##### **Technical description**

Water (rainwater, surface run-off etc.) from sealed surfaces that is collected and cannot be reused in the wood preservation process is treated (before discharge).

**Example plant C&G (mixed: WB and C plant)**

The water from the whole site is collected and treated prior to discharge. The waste water treatment plant takes the effluent to a holding tank and then treats it through a number of process stages to ensure it is suitable to be discharged from the site to the town drain which in turn feeds the South Forty Foot Drain. There are no discharges to the public sewer. [Q C&G 2017]

*(Technical details are missing on how water is collected, from which areas, if water may be impacted by pollution legacy (existing soil contamination), the treatment techniques applied etc. Clarifications are pending)*

**Achieved environmental benefits**

Reduced emissions to water.

**Environmental performance and operational data**

The example plant provided the data on emissions to water from their on site waste water treatment plant as presented in

Table 15.22. Measurements are made for compliance monitoring, No contextual information was submitted with regard to the measurements (e.g. frequency, monitoring standards/methods, and uncertainty of measurements).

Measured parameter	Waste water flow (m <sup>3</sup> /h)	Biocides (mg/l)	Cu (mg/l)	Cr (mg/l)	TOC [solvents] (mg/l)	PAHs (mg/l)	Benzo[a]pyrene (mg/l)
Average value (of samples taken during the monitoring exercise)	NI	NI	0.017	<0.002	NI	0.059	<0.01
Duration of monitoring exercise (h)	NI	NI	4	4	NI	4	4
Number of samples/measurements per monitoring exercise	NI	NI	20	20	NI	20	20
<i>Source: [Q C&amp;G 2017]</i>							

**Table 15.22: Emissions to water reported for 2016 by a mixed WPC plant (water-based and creosote treatment on site)**

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-8, SNCF, Marga, C&G,

**Reference literature** No information submitted.



#### 15.4.1.6.4 Disposal of waste water/collected potentially contaminated rainwater and surface run-off as hazardous waste

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.1.7 Energy consumption and efficiency

##### 15.4.1.7.1 Heat recovery from waste gases of thermal oxidation

###### **Description**

Waste heat from thermal oxidisers is used by means of heat exchangers to preheat the water for steam generation.

###### **Technical description**

Waste heat from thermal oxidisers is used by means of heat exchangers to preheat the water for steam generation.

###### **Example DE-1 (mixed: WB and C plant)**

For the layout and more technical details of plant DE-1 refer to Figure 15.30 showing the schematic of the creosote treatment.

###### **Achieved environmental benefits**

Reduction of energy consumption.

###### **Environmental performance and operational data**

###### **Example DE-1 (mixed: WB and C plant)**

Approximately 98 % of the company's natural gas (1,440,000 kWh/year) is used for steam generation. The steam generator has a capacity of 9.2 t/h. The actual steam generation is about 3.25 t/h. The temperature of the feed water is increased to 80 °C by means of a heat exchanger of the thermal exhaust gas purification and a pressure of 9 bar in the steam generator is reached with a 3.0 kW feed pump. The fan on the burner has a power of 7.0 kW and the circulating pump for distributing the steam of 1.09 kW.

Condensates are collected, treated and returned to the system by means of a condensate pump (0.55 kW).

The steam is used for heating of the creosote and for the steam fixation in the fixing system. The air emission values of the steam generator were once measured (but this is no longer required by the authority). [DE BAT study 2013]

**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

###### **Example plants**

DE-1

**Reference literature** No information submitted.

#### **15.4.1.8 Monitoring**

##### **15.4.1.8.1 Monitoring of waste water and surface run-off water**

###### **Description**

Waste water and surface run-off water that is not reused in the treatment process is analysed for content of pertinent pollutants, i.e. substances depending on the preservative type and biocides used in the treatment, e.g. solvents, specific active substances, metals.

###### **Technical description**

Waste water and surface run-off water that is not reused in the treatment process is analysed for content of pertinent pollutants, i.e. substances depending on the preservative type and the treatment chemicals/biocides used in the treatment, e.g. solvents, specific active substances, metals.

One MS provided information that it is a regulatory obligation to monitor the waste water at least annually if certain flow thresholds are exceeded (15 m<sup>3</sup>/h, 300 m<sup>3</sup>/d or 7500 m<sup>3</sup>/y). However, none of the plants from this MS took part in the data collection, therefore no further details on the monitoring are available. [IP BE 2014]

One mixed WPC plant (applying creosote (C) and water-based (WB) treatment) reported monitoring of emissions to water for the parameters: Cu, Cr, PAHs and benzo[a]pyrene, alas without giving information on monitoring frequencies or standards applied (see also 15.4.1.6.3). *(Very little information on monitoring of emissions to water was received via the questionnaires; although not all WPC plants are reusing 100% of the collected surface-run off water in their process and thus may be discharging waste water. TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

###### **Technical considerations relevant to applicability**

Monitoring should be carried out in situations where the local environment may be susceptible to biocides released from a plant. The appropriateness of the monitoring requirements will vary depending upon the sensitivity of the receiving water and should be proportionate to the scale of the operations, nature of the discharge and the receiving water. [OES auto 2016]

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

###### **Example plants**

Plants applying BAT candidate: DE-6, DE-5, Marga, Stella, Bitus, Octo, Varberg, C&G, FBI

**Reference literature** No information submitted.

##### **15.4.1.8.2 Monitoring of soil**

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Description** No information submitted.

**Technical description**

Of the plants that took part in the data collection exercise in 2017, 5 plants confirmed that soil pollution is monitored regularly (Track, C&G, Lonza, Sodra, WindyM) with frequencies of monitoring comprising 'as required', every 5 years or every 10 years.

**Example plant Track:**

Soil monitoring is done every 5 years and content of metals, Cu, Cr, benzo[a]pyrene, styrene, toluene, xylene, aromatic hydrocarbons, mineral oil, phenol, naphthalene and total PAH in the soil is determined (in mg/kg). The plant has identified historic soil and ground water pollution on site (baseline study in 2015).

The information available with regard to monitoring of soil (based on the plants that took part in the data collection) is summarised in Table 15.23 below.

**Table 15.23: Information on monitoring of soil contamination**

Plant	Plant type	Frequency monitoring	Parameters monitored (unit)
Track	mixed: WB+C	Every 5 years	Metals, Cu, Cr, benzo[a]pyrene, styrene, toluene, xylene, aromatic hydrocarbons, mineral oil, phenol, naphthalene, total PAH
C&G	mixed: WB+C	As required	NI
Lonza	water-based (WB)	Every 10 years	Biocides (mg/kg)
Sodra	water-based (WB)	Every 10 years	Biocides (mg/kg)
WindyM	water-based (WB)	Every 10 years	Cu, nitrate, 2-aminoethanol (monitored to show variation in concentrations)

Source: [WPC data collection 2017]

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate (soil and groundwater monitoring): DE-5, DE-9, Paras, ISB, SNCF, Oriel, PivB, Track, Bitus, C&G, Sodra, WindyM

**Reference literature** No information submitted.

**15.4.1.8.3 Monitoring of groundwater**

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Description** No information submitted.

**Technical description**

The information available with regard to monitoring of groundwater (based on the plants that took part in the data collection) is summarised in Table 15.24 below. No information was submitted on sampling or measurement standards used in groundwater monitoring. Three plants reported they have piezometers installed to control potential emissions to soil and groundwater.

Table 15.24: Information on monitoring of groundwater

Plant	Plant type	Frequency monitoring	Parameters (unit)
Froslev	water-based (WB)	Yearly	Cu, Cr, Ar, B ( $\mu\text{g/L}$ )
Lonza	water-based (WB)	NI	Azoles, Pyrethroids
Sodra	water-based (WB)	Every 2 years	Biocides ( $\mu\text{g/litre}$ ), COD
WindyM	water-based (WB)	Every 5 years	Cu, nitrate, 2-Aminoethanol (monitored to show variations)
Bitus	water-based (WB)	Twice per year	NI
Octo	mixed: WB+C	Twice per year	Metals, Cu, Cr, PAH, benzo[a]pyrene, oil
Oriel	water-based (WB)	Twice per year	propiconazole (%)
PivB	water-based (WB)	Twice per year	tébuconazole propiconazole, permethrine, cyperméthine, Cu ( $\mu\text{g}$ )
SNCF	creosote (C)	Twice per year	PAH, benzo[a]pyrene ( $\mu\text{g/l}$ )
Paras	water-based (WB)	Every 3 years	NI
DE-9	mixed: WB+C	Yearly (in future every two years)	PAH ( $\mu\text{M/l}$ ) naphtaline, BTEX (=sum of benzene, toluene, ethylbenzene and xylene), phenole, sulphate, nitrate, Fe (sulphate, nitrate and Fe only to prove that degradation is in progress)
DE-6	water-based (WB)	Twice per year	Cu
ISB	water-based (WB)	Twice per year	NI

Source: [WPC data collection 2017]

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

#### Example plants

Plants applying BAT candidate: DE-5, DE-9, Paras, ISB, SNCF, Oriel, PivB, Track, Bitus, C&G, Sodra, WindyM

**Reference literature** No information submitted.

#### 15.4.1.8.4 Monitoring of potential receiving surface waters in the vicinity of WPC plants

**Description** No information submitted.

#### Technical description

Of the plants that took part in the data collection three have potential receiving surface waters in the vicinity of the WPC plant; two reported that the surface water bodies are regularly monitored. At C&G plant the water is checked on an ad hoc basis by the competent authority; at Octo plant monitoring is done twice per year (no information available as to who is monitoring).

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

**Example plants**

Plant applying BAT candidate: Bitus (no information submitted in questionnaire), Octo, C&G

**Reference literature** No information submitted.

**15.4.1.8.5 Monitoring of emissions to air**

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Description** No information submitted.

**Technical description** No information submitted.

The information available with regard to monitoring of emissions to air (based on the plants that took part in the data collection) is summarised in Table 15.25 below.

**Table 15.25: Information on monitoring applied for emissions to air**

Plant	Purpose	Parameters monitored (units)
Octo	Compliance monitoring NO <sub>x</sub> / CO: continuous Others: periodic (every 3 years)	TOC (mgC/Nm <sup>3</sup> ) PAH (mg/Nm <sup>3</sup> ) PCDD/PCDF (TCSS-ekv I-TEQ) mg/h NO <sub>x</sub> , CO (mg/Nm <sup>3</sup> ) O <sub>2</sub> (%)
C&G	Compliance monitoring Yearly	PAH (including Naphthalene) ( mg/Nm <sup>3</sup> ) Total VOC (mg/Nm <sup>3</sup> )
DE-9	Compliance monitoring Periodic (every 3 years)	Waste gas flow (Nm <sup>3</sup> /h) TOC (mgC/Nm <sup>3</sup> ) NO <sub>x</sub> , CO (mg/Nm <sup>3</sup> ) O <sub>2</sub> (%)
SNCF	Compliance monitoring Yearly	Waste gas flow (Nm <sup>3</sup> /h) CMR-VOC (mgVOC/Nm <sup>3</sup> ) PAH (mg/Nm <sup>3</sup> ) Naphthalene (mg/Nm <sup>3</sup> ) Benzene (mg/Nm <sup>3</sup> )
Track	Compliance monitoring Yearly	TOC (mgC/Nm <sup>3</sup> )
DE-5	Compliance monitoring Periodic (every 3 years)	Benzene (mg/Nm <sup>3</sup> ) Benzo (a) pyrene (mg/m <sup>3</sup> ) Phenole (mg/m <sup>3</sup> )

Source: [WPC data collection 2017]

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-9, DE-5, SNCF, Track, C&G

**Reference literature** No information submitted.

### 15.4.1.9 Noise

Storage and handling of raw materials

#### 15.4.1.9.1 Installation of noise walls and utilisation/optimisation of noise-absorbing effect of buildings

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.1.9.2 Enclosure or partial enclosure of noisy operations

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.1.9.3 Use of low-noise vehicle transport systems

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.1.9.4 Noise management measures

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.

**Reference literature** No information submitted.

#### 15.4.1.9.5 Noise reduction measures for fans

**Description** No information submitted.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

### 15.4.2 Production-step-specific techniques to consider in the determination of BAT for wood preservation activities

#### 15.4.2.1 Delivery, reception, storage, mixing and transport of preservatives and other chemicals

##### 15.4.2.1.1 Back-venting displaced air to the delivery tank during filling of tanks

#### **Description**

Emissions to air, especially VOC, are controlled by back-venting displaced air to the delivery tank during filling of tanks (also referred to as vapour balancing).

#### **Technical description**

Emissions to air, especially VOC, are controlled by back-venting displaced air to the delivery tank during filling of tanks (also referred to as vapour balancing). Vapours which are displaced from the 'receiving tank' during filling are collected and returned to the tank or truck from which the liquid is delivered ('delivery tank?'). Such balancing systems require the receiving and delivery tanks to be of the fixed roof type to permit vapour collection and transfer.

More details are given in EFS (Emissions from Storage) BREF.

#### **Achieved environmental benefits**

Reduction of emissions to air, especially VOCs.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

#### **Technical considerations relevant to applicability**

Applicable to plants using solvent-based preservatives or creosote.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

##### 15.4.2.1.2 Capture of displaced air during filling of tanks and treatment of these off-gases

#### **Description**

Capture of displaced air during filling of tanks and treatment of these off-gases.

**Technical description**

Emissions to air, especially VOC, are controlled by capture and treatment of air that is displaced from a tank during filling. Vapours which are displaced from the ‘receiving tank’ during filling are collected and led to a treatment unit, e.g. activated carbon filter or thermal oxidation unit (treating emissions from impregnation process).

**Example DE-1 (mixed: WB and C plant)**

In the creosote treatment line the storage tanks are filled by means of trucks. The air which is displaced during the filling of the storage containers (also during the backpumping of the tar oil from the working container) is conducted to a collecting container (S1) in which the gas, water and tar oil are separated. The three phases are treated differently:

The gas phase is cleaned in a thermal exhaust air purification plant (thermal exhaust gas purification TAR).

The water (approximately 0.5–1 m<sup>3</sup> per load depending on the wood moisture) is pumped to the production line Korasit CK and used there or in rare cases it is disposed of as waste by tanker (waste code number 130899 \*, 40 m<sup>3</sup> / year, declaration analysis available / required).

The tar oil is returned to the system by means of a vacuum in the working tank. [DE BAT study 2013]

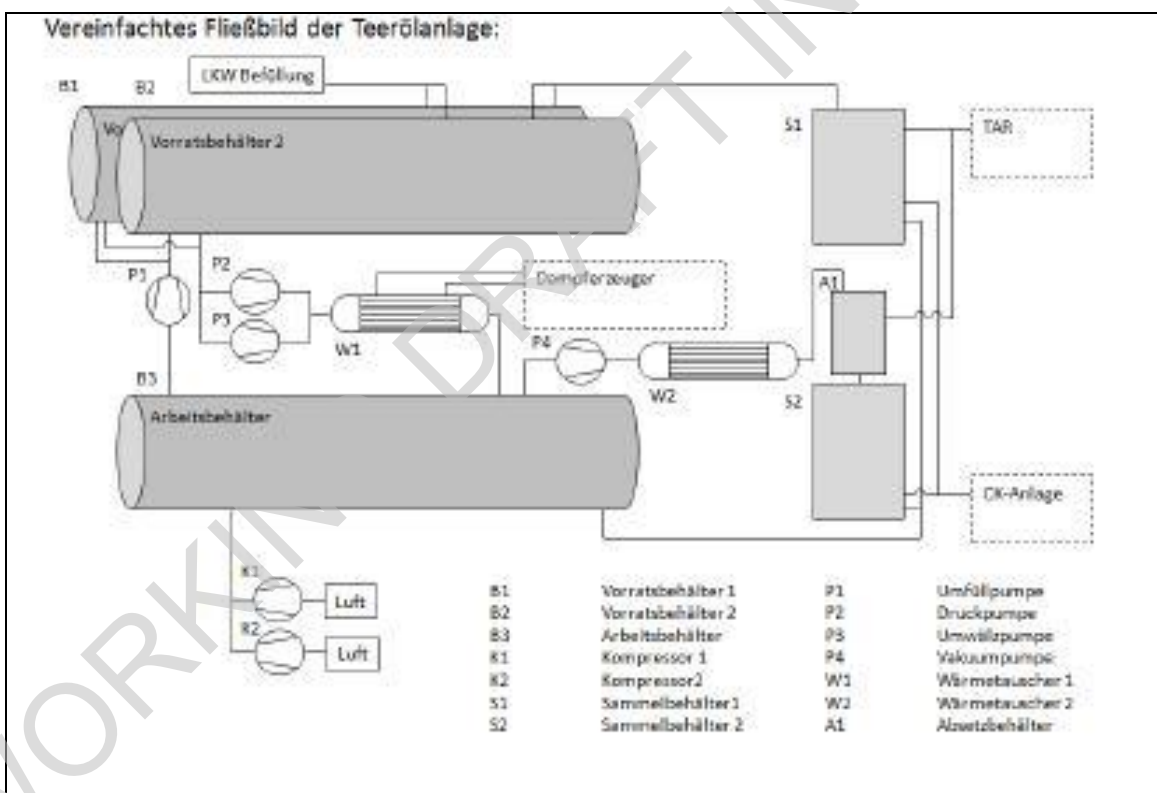


Figure 15.24: Schematic of the creosote pressure treatment plant DE 1 [DE BAT study 2013]

**Achieved environmental benefits**

Reduction of emissions to air, especially VOCs.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.



**Technical considerations relevant to applicability**

Applicable to plants using solvent-based preservatives or creosote.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.2.1.3 Submerged loading or bottom loading****Description**

For submerged loading the fill pipe is extended nearly to the bottom of the tank so that the fill pipe opening is under the liquid level most of the time. For of bottom loading, the fill pipe is attached to the tank bottom.

**Technical description**

Submerged and bottom loading can decrease the VOC emissions to air while loading tanks. In the case of submerged loading, the fill pipe is extended nearly to the bottom of the tank so that the fill pipe opening is under the liquid level most of the time. In the case of bottom loading, the fill pipe is attached to the tank bottom.

**Achieved environmental benefits**

Reduction of emissions to air, especially VOCs.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**

Applicable to plants using solvent-based preservatives or creosote.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.2.1.4 Filling pipe installed high enough above the fluid surface level**

*(Contradicting information provided, also in relation to BAT candidate ' Submerged loading or bottom loading' above. TWG is kindly asked to provide clarifications*

**Description**

Filling pipe (for preservative fluids) installed high enough above the fluid surface level in the storage tanks, dipping and mixing tanks, in order to prevent a siphon effect that allows the preservation fluid (to flow) backwards.

**Technical description**

Filling pipe (for preservative fluids) installed high enough above the fluid surface level in the storage tanks, dipping and mixing tanks, in order to prevent a siphon effect that allows the preservation fluid (to flow) backwards. [Norden BAT study 2014]

The risk of a filling pipe back siphoning can be eliminated by having the discharge point of the filling pipe positioned high enough above the height of the maximum level of liquid which the receiving tank might receive. Such a device is required to have a siphon break in the water supply to mixing tanks to prevent wood preservative solution from being sucked back into the water mains system as a result of a fall in the water supply pressure. (NB: Non-return valves are not permitted by water authorities.) [comment FI?]

When water comes from the public water system or groundwater, installations are equipped with a non-return valve in order to prevent wood preservative solution from being sucked back into the water mains system. [OES auto 2016]

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**  
Applicable to all three preservative types.

**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.2.1.5 Automatic protection system against overflowing of storage tanks, mixing tanks and cylinders

##### **Description**

A device or system is fitted to prevent the overflowing of the mixing tanks or storage.

##### **Technical description**

A device or system can be fitted to prevent the overflowing of the mixing tanks or storage tanks and filling the bund. Such a device could also include a device for pre-setting the water volume when preparing the fresh treatment solution or when adjusting treatment solution strengths. This minimises the risk of an overflow, even if a filling height shut-off is installed in the tank.

Security devices are in place in order to avoid overflowing. Very often, automatic devices exist for the mixing tank for its filling with the required quantities of water and wood preservative. Tanks are fixed with the presence of a gauge. Tanks are located in a masonry (or similar) pit, with the presence of filling limiter. Reserves of absorbents are in proximity to absorb limited eventual leaks. [OES auto 2016]

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**  
Applicable to all preservative types.

**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.2.1.6 Above-ground storage tanks for creosote: heating

##### **Description**

Below a certain temperature creosote crystallises and blocks the pipes; heating is provided if outside temperature is too low. The tanks are always heated, at least in northern Europe.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**

Applicable to creosote plants.

**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

**15.4.2.1.7 Light-coloured paint coating to reduce heating up of stored chemicals (for above-ground storage tanks for creosote)**

**Description** No information submitted.

**Technical description**

The tank colour influences the amount of thermal or light radiation absorbed by above-ground tanks and, therefore, the temperature of the liquid and vapour contents inside. This measure is applicable for all types of aboveground tanks. The impact of the tank colour is limited if the tank is already fitted with a floating roof. (EFS BREF page 126)

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

**15.4.2.1.8 Underground storage tanks (existing): Lining with impermeable foil and equipped with a leachate warning system**

**Description** No information submitted.

**Technical description**

Underground storage tanks are defined as being below the ground surface and covered. This is in contrast to a tank which is situated below the ground surface but open to the sky. Its surfaces can be inspected. Such storage facilities should be covered by a roof so that incident rainwater does not enter the pit and compromise the bunds' holding capacity.

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

**15.4.2.1.9 Closed storage containers for materials containing solvents and/or biocides**

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

**15.4.2.1.10 Mixing of preservation fluid in closed system**

**Description** No information submitted.

**Technical description**

Wood preservatives may be supplied to the treatment site in a concentrate or a ready-for-use form. The ready-for-use form is delivered directly to the storage tank and drawn to and from the treatment vessel. Concentrate products may be supplied in IBCs and their contents withdrawn from the containers using a discharge system. Alternatively the concentrate product may be discharged from a bulk container into a concentrate storage tank. All these product transfers take place in a closed pipework and circulation system.

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**

Applicable to all three preservative types.

**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

**15.4.2.1.11 Exhaust gas capture and air abatement system for releases during inspection or cleaning of storage tanks**

**Description** No information submitted.

**Technical description**

Treatment in a thermal oxidiser or equivalent emission control measures for exhaust gases released during inspection or cleaning of the storage tanks.

SE: Systems for capturing exhaust gases when inspecting/cleaning storage tanks are probably not very common. Measures for safe work inside the tanks will be different for creosote plants and plants using water-borne preservatives.

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**

Applicable to plants using solvent-based preservatives or creosote.

**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.2.2 Preparation /Conditioning of wood

##### 15.4.2.2.1 Collection and treatment of condense water from kiln drying

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

##### 15.4.2.2.2 Measurement of wood moisture before treatment

###### Description

Wood moisture is measured by electric resistance measurement or by weighing procedures to optimise the impregnation process and ensure the required product quality. [OES auto 2016]

###### Technical description

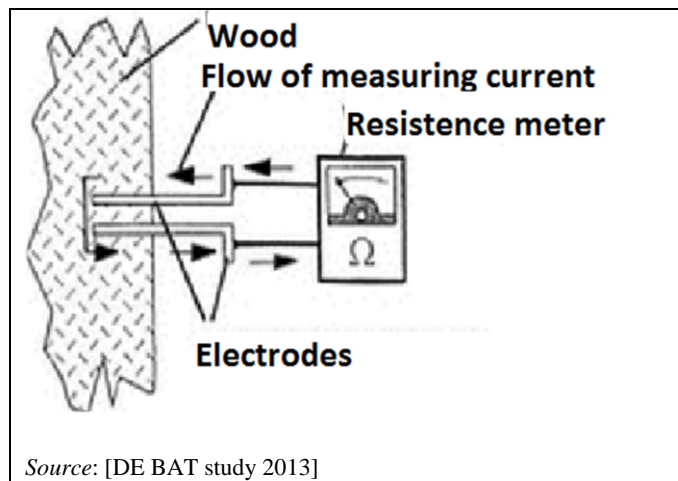
Any impregnation process requires a certain level of wood moisture, in order to achieve the optimum result of the impregnation. Measuring the wood moisture before impregnation and - if needed - adjustment of wood moisture ensure the required quality of the impregnated wood. Wood with suboptimal moisture content is brought to the optimal wood humidity level before the treatment (e.g. by extending seasoning (air drying) or by active drying (kiln drying)). Thus the need for repeated impregnation is avoided.

Determining the moisture content ('impregnating maturity') can be done by:

- a) electric resistance measurement (manual or automated);
- b) weighing procedures.

###### a) Electric resistance measurement

The electric resistance of wood increases with decreasing moisture. The electrical resistance is measured and transformed into a moisture value. The basic principle of electric wood moisture measurement is shown in Figure 15.26.



**Figure 15.25:** Basic principle of electric resistance wood moisture measurement

The measurement is either done manually, using a handset for electric resistance measurement (see Figure 15.27 below), or performed automatically.



**Figure 15.26:** Manual wood moisture measurement

Automatic electrical resistance measurement is supported by a computer and the measured values can be digitally recorded and documented.

An example for an automatic measurement procedure (applied in mast production) is given below:

- Issuing table for the automatic separation of the load and feeding of individual trunks in the measuring system.
- Electrodes penetrate about 5–6 cm (sapwood heartwood boundary) in the raw wood (in the case of masts, usually the measurement area is on the soil-air boundary, as approximately a sixth of the mast is dug into the ground).
- Four transducers/sensors are used for detecting moisture nests (which arise in particular from the storage of wood).
- If the measurement of humidity is not optimal, the measurement is repeated at the point 30 cm above and below the first measuring point. If the moisture content is not correct after the second measurement, the raw wood must be dried further.

- When the optimal moisture content is reached, each mast is allocated with a number and conveyed to the treatment vessel where impregnation is carried out.

b) Weighing procedures      No information submitted.

#### **Achieved environmental benefits**

Reduced consumption of resources such as wood preservatives, wood and energy (by avoiding repeated impregnation).

The wood moisture measurement will ensure the required quality of impregnated wood and contributes to a reduction in the use of the required resources such as wood preservatives, wood and energy (by avoiding repeated impregnation, increasing the durability of the products and reducing/preventing early failure).

#### **Environmental performance and operational data**

- According to operators - simple, robust and reliable technology.
- Significant reduction in the rate of return (Plant DE-1 indicated that the return rate was reduced from 30% to 15%), thus optimising storage utilisation.

**Cross-media effects**      No information submitted.

#### **Technical considerations relevant to applicability**

a) Applicable to wood with a moisture between 7 % and 30 %.

#### **Economics**

##### Manual measurement of resistance

No information on costs provided, but the costs are generally regarded to be low.

##### Automatic measurement of resistance

- Investment costs of Plant DE-3: approximately EUR 300 000-400 000 (payback period approximately 10 years).
- Operating costs of Plant DE-3: electrodes: 1 pin = EUR 4 (pin consumption approximately 350-400 pieces/year).
- Estimated staff costs of Plant DE-3: EUR 70–80/year (1.5 employees).
- Prevention of failures and associated warranty can be very expensive (EUR 250–500 for a new mast and approximately EUR 1 000 for the replacement of the mast; training and installation costs).

#### **Driving force for implementation**

- Higher quality of products.
- Exact wood moisture determination is of crucial importance in the application of non-creeping wood preservatives.

#### **Example plants**

Automatic resistance measurement: Plant DE-3.

Manual resistance measurement (handset): Plant DE-1, Plant DE-2. Handsets for raw wood moisture determination are in use Europe-wide.

#### **Reference literature**

Moisture content of a piece of lumber - DIN EN 13183-1 (determination by Darren procedure, DIN EN 13183-2 (estimated by electrical resistance measurement), DIN EN 13183-3 (estimated by capacitive measuring method)

#### **15.4.2.2.3      Removal of debris from wood before the wood is treated**

**Description**

Debris is removed from the surface of the wood/wood products by blowing air through the batch of wood to be treated.

**Technical description**

Different methods are available to remove debris from the surface of the wood items; one way is 'purging'. Blowing air through the batch of wood to be treated, removes sawdust and other 'impurities'.

**Achieved environmental benefits**

Reduced need for retreatment, reduced consumption of chemicals and reduced generation of waste (e.g. amount of sludge in the treatment vessel).

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.2.2.4 Removal of plastic wrap from wood packs prior to treatment**

**Description**

Plastic wrappings are removed from wood packs to avoid wood preservatives being trapped in the plastic and being emitted after treatment (e.g. as drippings) or generating hazardous waste (i.e. contaminated plastic waste).

**Technical description**

Packs of timber are invariably transported protected in plastic-based sheeting to protect the timber and prevent it taking up moisture during its time from preparation to the end use application. Such plastic sheets may trap liquid wood preservative in folds in the plastic which may be released from the treated pack when it is moved. The plastic is also contaminated with wood preservative and needs to be handled as hazardous waste. [OES auto 2016]

**Achieved environmental benefits**

No trapping of treatment solution, thus prevention of spills/soil contamination.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**

Only applicable to wood/wood products that are delivered to the WPC plant in wrapping. Poles, for example, may be delivered without any wrapping. [Q Stella 2017]

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.2.2.5 Optimisation of wood charge preparation**

**Description**

The way wood or wood items are bundled/piled or loaded into the treatment vessel has an impact on the quality of the treated wood, but also on the emissions from the process. The basic



principles of optimised wood loads are free access, free drainage and non-trapping of preservative solution. This is achieved by:

- a) separation of wood in packs by spacers;
- b) sloping of wood packs
- c) using tilting treatment vessels);
- d) positioning shaped profiles in such a way so as to prevent ponding/trapping of treatment solution;
- e) securing wood packs/pieces to prevent wood lifting during treatment;
- f) avoiding flat areas or trap areas on loading systems;
- g) maximising wood load.

### **Technical description**

Several techniques can be applied to optimise the preparation of the wood charge (i.e. how the wood is charged into the treatment vessel). The main aim is to allow free movement of preservative solution through the wood items to ensure impregnation quality, but at the same time these measures allow for optimum draining of preservative solution after treatment, thus reducing consumption and drag-out of preservatives, and the risk of emission to the environment. The following measures are applied:

#### ***a) Separation of wood in packs by spacers***

Timbers which are being presented for treatment in packs usually have spacers (stickers). They are placed at regular intervals in the pack to aid movement of the wood preservative through the pack of timber and also help in the draining and recovery of excess wood preservative at the end of the treatment cycle. However, in some cases (e.g. for cladding) spacers cannot be used as they would cause marks the surface of the timber. [OES auto 2016]

#### ***b) Sloping of wood packs in traditional horizontal treatment vessels***

An inclined arrangement of the wood packs facilitates the flow of wood preservatives and draining after the treatment.

#### ***c) Use of tilting pressure treatment vessels***

Some larger autoclave plants with a large wood throughput alternatively use tilting vessels. These allow for the whole vessel to be inclined after the treatment process; excess treatment solution drains easily and can be recovered from the bottom of the vessel.

#### ***d) Positioning shaped profiles in a way so as to prevent ponding/trapping of treatment solution***

#### ***e) Securing wood packs/pieces to prevent wood lifting during treatment***

The wood packs are secured or prevented from floating free in the vessel. There are a number of options being used dependent upon packs / commodities being treated:

1. Pack straps or chains to hold timbers to the bogie. This gives greatest flexibility and allows for uneven packs and small packs put on top of other packs etc. The majority of plants work in this way.
2. Side arms on the bogie allow the timbers to move during treatment but then return to the bogie when the vessel empties. They are used infrequently but work well where the pack size is close to that of the vessel. Timber bearers are placed on top of the packs to stop the packs hitting the top of the vessel.
3. Hydraulic clamping of the timbers within the vessel. This can be applied with or without a bogie depending on the timber handling system design. It works best where packs are all of similar dimensions. When there are big differences in pack heights, additional spacer sections are placed on top of small packs to level out the charge and ensure clamps hold the packs. [EWPM\_WEI tech info 4-2016]

f) *Avoiding flat areas or trap areas on loading systems*

g) *Maximising wood load*

**Achieved environmental benefits**

Reduced consumption of preservatives, energy etc. due to less retreatment, reduced waste generation and reduced emissions of preservative solution.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

b) Due to higher investment costs of tilting vessels, a large volume of wood/wood throughput is required for amortisation.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.2.3 Preservative application process / Non-pressure processes**

**15.4.2.3.1 Enclosure for spraying and spray tunnels (plus gas extraction and emission abatement system)**

**Description** No information submitted.

Spraying units are sealed against the ambient air.

**Technical description**

Enclosing the process wherever possible so that air can be extracted through abatement equipment thermal oxidation or adsorption with solvent recovery. [STS BREF 2007]

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.2.3.2 Enclosure for bath processes: dipping and immersion (plus gas extraction and emission abatement system)**

**Description** No information submitted.

Enclosing the process wherever possible so that air can be extracted through abatement equipment, thermal oxidation or adsorption with solvent recovery. [STS BREF 2007]

**Technical description**

Emissions to air from bath processes (dipping, immersion) can be reduced by enclosing the process and extracting and treating the gaseous emissions. Different technical solutions are possible:

- a) Lid on tank when immersing in solvent-based preservative plus extraction system with vapour treatment [BE IP]. No information submitted.
- b) Exhaust gas capture for hot-cold bath (creosote) treatment (see Section 15.4.3.3.6).

**Achieved environmental benefits**

Reduction/capture of diffuse emissions.

Reduction of emissions to air, especially VOC and PAH.

**Environmental performance and operational data** No information submitted.**Cross-media effects** No information submitted.**Technical considerations relevant to applicability** No information submitted.**Economics** No information submitted.**Driving force for implementation** No information submitted.**Example plants** No information submitted.**Reference literature** No information submitted.**15.4.2.3.3 Sufficiently large and wood-preservative-resistant containment, fender and automatic leak detection device in the case of non-visible containment****Description** No information submitted.**Technical description** No information submitted.**Achieved environmental benefits** No information submitted.**Environmental performance and operational data** No information submitted.**Cross-media effects** No information submitted.**Technical considerations relevant to applicability** No information submitted.

Applicable to existing single-wall treatment vessels

**Economics** No information submitted.**Driving force for implementation** No information submitted.**Example plants** No information submitted.**Reference literature** No information submitted.**15.4.2.3.4 Double-wall impregnation tanks with leak detection device****Description** No information submitted.**Technical description** No information submitted.**Achieved environmental benefits** No information submitted.**Environmental performance and operational data** No information submitted.**Cross-media effects** No information submitted.**Technical considerations relevant to applicability** No information submitted.**Economics** No information submitted.**Driving force for implementation** No information submitted.**Example plants** No information submitted.**Reference literature** No information submitted.**15.4.2.3.5 Sufficient dripping time after treatment (dripping into treatment vessel)****Description** No information submitted.**Technical description**

After the treatment with preservatives, the treated wood is held for a minimum time over the treatment vessel to allow surplus treatment solution to drip into the treatment vessel or the wood is held over a dripping pad which inclines towards the treatment vessels and allows the

drippings to flow to the dipping vessels, thus avoiding the release of preservatives from the tanks or vessels.



Figure 15.27: Example of a drip pad with dripping treatment solution flowing back into the treatment vessel

- Achieved environmental benefits** No information submitted.
- Environmental performance and operational data** No information submitted.
- Cross-media effects** No information submitted.
- Technical considerations relevant to applicability** No information submitted.
- Economics** No information submitted.
- Driving force for implementation** No information submitted.
- Example plants** No information submitted.
- Reference literature** No information submitted.

**15.4.2.3.6 Drip test to ensure that wood is 'dry' prior to removal from the contained area**

**Description** No information submitted.

**Technical description**

Packs of wood are lifted by mechanical means and suspended above the post-treatment drying area for a minimum of five minutes. If no drips fall or form during this period the wood pack is deemed dry and can be removed.

- Achieved environmental benefits** No information submitted.
- Environmental performance and operational data** No information submitted.
- Cross-media effects** No information submitted.
- Technical considerations relevant to applicability** No information submitted.
- Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

#### 15.4.2.4 Preservative application process / Pressure processes

##### 15.4.2.4.1 Precautionary design features for pressure treatment vessels (autoclaves)

###### Description

Precautionary design features for pressure treatment vessels (autoclaves) comprise the following techniques:

- a) Safety lock for vessel door
- b) Process controls displaying whether liquid is present in the treatment vessel
- c) Process controls prevent the treatment vessel from opening before all preservative solution is removed from the treatment vessel
- d) Catch-lock for the treatment vessel door
- e) Safety pressure-relief valves

###### Technical description

a) Safety locks for vessel door: the treatment vessel is locked shut and sealed once the wood pack/vessel loading system is loaded and before treatment takes place. Process controls are in place that prevent the operation of the treatment vessel unless the vessel is locked and sealed

b) Process controls displaying whether liquid is present in the treatment vessel

c) Process controls prevent the treatment vessel from opening before all preservative solution is removed from the treatment vessel: process controls prevent the opening of the treatment vessel while it is still pressurised and/or filled

d) Catch-lock for the treatment vessel door: the door of the treatment vessel is equipped with a catch-lock to prevent the release of fluid in case the treatment vessel door needs to be opened in an emergency situation.

e) Safety pressure-relief valves: treatment vessels are fitted with safety relief valves to allow emptying of vessel in a controlled manner. The valves are designed to ensure that any discharge is directed to a tank of sufficient capacity. Pressure/vacuum-relief valves are examined at least once every six months for signs of corrosion, contamination, incorrect fitting and to be cleaned and/or corrected as required.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

##### 15.4.2.4.2 Control of aerosol emissions from vacuum pump exhaust

###### Description

Air extracted from pressure treatment vessels (vacuum pump outlet) is treated by liquid separators or is directed to a settling tank.

###### Technical description

**Example DE-1 (mixed: WB and C plant)**

Vacuum pumps are used to create the vacuum in the treatment vessel. In order to prevent aerosols from entering the environment, the extracted air from the water-based treatment vessels is directed to a settling tank (5 m<sup>3</sup>) which contains the cooling water of the vacuum pump.

The use of liquid separators on the discharge side of vacuum pumps to avoid the release of preservatives via aerosols was also reported as a technique, but no information was provided. [AT IP 2014] *(The TWG is asked to provide more examples and/or technical details for this BAT candidate, including performance data.)*

**Achieved environmental benefits**

Reduction of emissions to air/aerosols.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**

Applicable to all preservative types.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

DE-1

**Reference literature** No information submitted.

**15.4.2.4.3 Reduction of aerosol emissions by allowing sufficient time between pressure balance and opening of the treatment vessel**

**Description**

Minimisation of aerosol emissions by leaving sufficient time between pressure balance and opening of the boiler.

**Technical description**

To prevent or reduce aerosol formation and emissions, pressure processes can be operated with a drip-off and/or condensation phase at the end of the impregnation process before the treatment vessel is opened for removing the treated wood. [VDI 3462 draft 2014].

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.2.4.4 Safety measures to avoid opening of vessel door during impregnation**

**Description** No information submitted.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### 15.4.2.4.5 Application of final vacuum to remove excess preservatives

##### Description

Emissions when opening the treatment vessel are reduced by applying a final vacuum that removes all surplus treatment solution.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

#### 15.4.2.4.6 Discharge of exhaust gases from pressure relief valves and drain facilities into the gas collection system or feeding into exhaust gas treatment system

##### Description

Discharge of exhaust gases from pressure relief valves and drainage facilities into the gas collection system or feeding into exhaust gas treatment system.

##### Technical description

###### *Example DE-1 (mixed: WB and C plant)*

The air, which is displaced from the working container or is pumped out by the vacuum pump P4 (18.5 kW), is cooled by a heat exchanger W2 and collected in a settling container A1. The gas phase is passed from the settling tank to the thermal exhaust air purification system. The existing liquid phase consisting of water and tar oil is intermediately stored in a collecting container S2. The aqueous phase can be reused in the production line of the Korasit CK. The tar oil is sucked back into the system by means of a vacuum in the working tank. [DE BAT study 2013]

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

#### 15.4.2.5 Energy consumption and energy efficiency

##### 15.4.2.5.1 Variable pump control

##### Description

After reaching the required working pressure, the system is switched to a pump with reduced performance and energy consumption. [DE BAT study 2013]

**Technical description**

A pressure pump with relatively high power is used for building the desired working pressure in the treatment vessel. After reaching the working pressure, the system is switched to a more energy-efficient pressure pump with lower power. [DE BAT study 2013]

**Achieved environmental benefits**

Reduction in energy consumption [DE BAT study 2013]

**Environmental performance and operational data**

The operator estimates a reduction of energy consumption of 25 % (6 000 kWh/a/pump). [DE BAT study 2013]

**Cross-media effects**

None.

**Technical considerations relevant to applicability**

The technique is generally applicable both to existing and new installations. [DE BAT study 2013]

**Economics**

Investment costs: approximately EUR 5 000 (payback period at an average price of electricity for industrial customers in Germany in 2011 (EUR 0.113/kWh): approximately seven years). [DE BAT study 2013]

**Driving force for application**

Reduction of energy consumption (cost savings) [DE BAT study 2013].

**Example installation**

DE Installation 1.

**Reference literature** No information submitted.

**15.4.2.6 Process vessel cleaning**

**15.4.2.6.1 Rotary spray nozzle heads**

**Description**

The use of rotary spray nozzle heads (or similar means) and the reuse of the water reduce the volume of cleaning water.

**Technical description**

The use of rotary spray nozzle heads (or similar means) and the reuse of the water reduce the volume of cleaning water. [UK SG11 draft 2013]

**Achieved environmental benefits**

Reduced volume of cleaning water.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.



**Reference literature** No information submitted.

#### 15.4.2.7 Post-treatment conditioning and interim storage

##### 15.4.2.7.1 Post-treatment in proximity to treatment

**Description** No information submitted.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

##### 15.4.2.7.2 Roof over extracting rail area, drip area (drying area) and fixing area

###### **Description**

A roof covering the treatment area and/or of the storage area for freshly treated wood protects the treated timber against weather/rainfall during the transport and storage until the complete fixation of the wood preservative. Rainwater is stopped from entering the impregnation installation and leaching of non-fixed wood preservatives is prevented.

###### **Technical description**

###### **Example plant DE-2:**

The area of extraction rails as well as the transport area to the storage areas for fresh impregnated wood (storage under the roof for at least two days, often longer) are covered and protected from the sides against the wind and rain (a new roof is under construction: roof, rafters/purlin roof structure with profiled sheeting partially with insulation and roof covering made of PVC). The relevant area of the roof is approximately 2 500 m<sup>2</sup>. [DE BAT study 2013]

###### **Example plant DE-4:**

Roofing in the area of troughs and the drip area is for the protection against rain and wind-driven rain and there is additional equipment for prevention of surface water accession.

The gradient of the adjacent transportation areas is directed away from the building so that surface water cannot access the impregnation area.

The roofing in the fixing area serves as protection against rain and wind-driven rain and washing out of non-fixed wood preservatives.

Storage under the roof depends on the product properties as well as the geometry of the impregnated wood. Besides, the fixing time depends on applied wood preservatives and the weather conditions. In spring to autumn, the fixing time is approximately 24 hours. For the winter months, no representative data are available. The roof in the area of troughs and the drip area is approximately 150–200 m<sup>2</sup> (equivalent to the roof in the area of troughs including drip area without fixing storage and storage for impregnating agents). The roof of the fixing storage measures about 200 m<sup>2</sup>.



Source: [DE BAT study 2013]

**Figure 15.28:** Example of a roof cover in the area of troughs (plant DE-4)

### **Achieved environmental benefits**

#### ***Example plant DE-2:***

After the impregnation, the treated wood is exclusively transported and stored under the roof for at least two days until the complete fixation (after 48 hours) of the self-fixating wood preservative. This ensures that the wood preservatives cannot be washed out by the rain prior to full fixation.

#### ***Example plant DE-4:***

The wood is dry stored after impregnation until the complete fixation in the fixing storage. This ensures that the wood preservatives cannot be washed out by the rain prior to full fixation. [DE BAT study 2013]

### **Environmental performance and operational data**

#### ***Example plant DE-2:***

Washing out of non-fixed wood preservatives is prevented.

#### ***Example plant DE-4:***

Through the existing drainer and subsequent storage in the fixing storage (covered), it is ensured that the fixation is completed and the leaching of not fixed wood preservative is reduced to a minimum. [DE BAT study 2013]

### **Cross-media effects**

None.

### **Technical considerations relevant to applicability**

Technology is generally applicable both to existing and new installations. [DE BAT study 2013]

### **Economics**

#### ***Example plant DE-2:***

- Investment costs: approximately EUR 40/m<sup>2</sup> roof surface.
- Operating and maintenance costs are negligible.

#### ***Example plant DE-4:***

- Investment costs: no specifications as the impregnation area is situated in the hall.
- Operating and maintenance costs are negligible. [DE BAT study 2013]

**Driving force for implementation****Example plant DE-2:**

- Quality assurance (prevents the leaching of wood preservatives by precipitation).
- Prevents the process cycle from storm water (precipitation water would enter in too large quantities via the inlet chute of the storage into the drip tray) [DE BAT study 2013]

**Example installation**

DE-2, DE-4

**Reference literature**

VDI Directive [VDI 3462 draft 2014]

**15.4.2.7.3 Covered and/or contained and impermeable dripping area for freshly treated timber****Description** No information submitted.**Technical description** No information submitted.**Achieved environmental benefits** No information submitted.**Environmental performance and operational data** No information submitted.**Cross-media effects** No information submitted.**Technical considerations relevant to applicability** No information submitted.**Economics** No information submitted.**Driving force for implementation** No information submitted.**Example plants** No information submitted.**Reference literature** No information submitted.**15.4.2.7.4 Storage under tarpaulins until the complete fixation****Description**

Freshly treated wood is stored under tarpaulins until the wood preservatives are completely fixed. [Q Stella 2017]

**Technical description** No information submitted.**Achieved environmental benefits** No information submitted.**Environmental performance and operational data** No information submitted.**Cross-media effects** No information submitted.**Technical considerations relevant to applicability** No information submitted.**Economics** No information submitted.**Driving force for implementation** No information submitted.**Example plants** No information submitted.**Reference literature** No information submitted.**15.4.2.7.5 Collection and treatment of leaching water for open (roof-less) storage of treated wood***(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).***Description** No information submitted.**Technical description** No information submitted.**Achieved environmental benefits** No information submitted.**Environmental performance and operational data** No information submitted.**Cross-media effects** No information submitted.**Technical considerations relevant to applicability** No information submitted.**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-5, Froslev, SNCF, Track, C&G,

**Reference literature** No information submitted.

**15.4.2.7.6 Fixation by steam (autoclave) or warm air (climate chamber) after preservation treatment**

**Description** No information submitted.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: Paras, Bitus

**Reference literature** No information submitted.

**15.4.2.7.7 Avoidance of contact of freshly treated wood with the floor**

**Description**

Avoidance of contact with the ground of freshly impregnated wood, and sufficient ventilation at ground level, accelerates fixation. *(Technique proposed as additional BAT candidate in IP call (AT), but no information was submitted.)*

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.2.7.8 Removal of treated wood from working area only after fixation stage (minimum holding time)**

**Description**

Long enough dripping of preserved wood to reach the fixation stage before removal from the working area minimises leaching in the storage area.

**Technical description**

*(TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

#### **Example plants**

Plants applying BAT candidate: DE-6, DE-5, DE-9, DE-8, Froslev, Paras, ISB, SNCF, Oriel, PivB, Marga, Stella, Track, Bitus, Varberg, C&G, Lonza, Sodra, WindyM,

**Reference literature** No information submitted.

#### **15.4.2.7.9 Drip test**

##### **Description**

Treated wood/wood packs are lifted by mechanical means and suspended above the post-treatment drying area for a minimum of five minutes. If no drippage of treatment solution occurs, the wood is deemed dry.

##### **Technical description**

To be defined as dry, a pack shall be lifted by mechanical means and shall be suspended above the post-treatment drying area for a minimum of five minutes. The pack should not form drips or drip treatment solution during this period. Wood packs remain on the post-treatment drying area until the packs are defined as dry. [UK SG11 draft 2013]

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

#### **15.4.2.8 Treatment/impregnating with hydrophobing agents**

##### **15.4.2.8.1 Recirculation of wax and oils**

*(Technique proposed as additional BAT candidate in IP call (DE), but no information was submitted. TWG is kindly asked to provide information (10 heading structure for BAT candidates) for the plants that apply the BAT candidate (see list/example plants)).*

##### **Description**

Redundant (overflow) wax or oils from the impregnation process are collected and recirculated.

**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

##### **Example plants**

Plant applying BAT candidate: Marga

**Reference literature** No information submitted.

### 15.4.3 Preservative type-specific techniques to consider in the determination of BAT for wood preservation activities

#### 15.4.3.1 Water-based preservatives

##### 15.4.3.1.1 Substitution of chromium-containing protective products with chromium-free products

#### Description

Substitution of chromium-containing protective products with chromium-free products.

#### Technical description

*Example plant DE-3 (text as provided, editing will be done at a later stage)*

The plant converted the impregnation process from chrome-containing wood preservatives to chromium-free in 2010. Water-soluble, liquid, fixating wood preservatives are used on the basis of copper complex compounds and a quaternary ammonium compound.

The impregnation installation and the impregnating process needed to be adapted to the applied preservatives (e.g. structural measures, reduced vessel filling level due to formation of foam, respecting the process parameters, etc.). [DE BAT study 2013]

#### Achieved environmental benefits

The chrome-free copper-containing preservative is not mobile, i.e. it has no creep properties, also in the wood (there is no 'flowing'). Chromium-free preservatives are, in contrast to chromium-containing products, immobile in the soil. Chromium-containing wood preservatives can cause environmental pollution of the groundwater and related contaminated site, due to mobile properties of chromium VI (CR VI is mobile; after fixation it transferred to CR III which is immobile). [DE BAT study 2013]

The chrome-free wood preservatives are self-fixing and the fixing process is relatively fast (binding on the wood fibre; after 12 hours ~ 97 %; after 48 hours ~ 99 %). [DE BAT study 2013]

#### Environmental performance and operational data

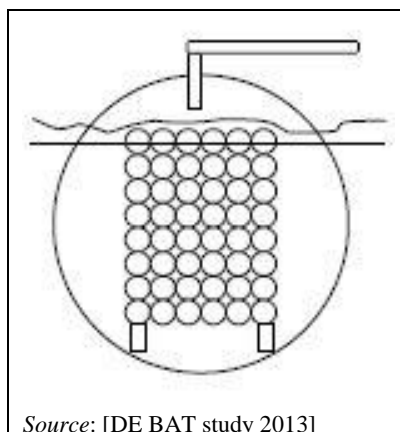
Due to the properties of chrome-free preservatives, the system parameters have to be more accurately followed, as before the substitution (this requires additional controlling measures such as viscometer, electrical measurement, switching from the acidic (pH 3-4) to alkaline medium (pH 10.2–10.4)). [DE BAT study 2013]

In the container containing wood preservative, the salt components can sink to the bottom of the tank; it is a partial segregation. After longer non-operating times (e.g. during the weekends), the container contents need to be stirred before use in order to mix the wood preservative components. [DE BAT study 2013]

In Plant DE-3 which uses chromium-free wood preservatives, the vacuum must be gradually applied to reduce the foaming of the alkaline medium. Further on a stronger vacuum is required to reach the required depth of impregnation (since the chromium-free preservatives have no creep properties, the stronger vacuum is required to reach the heartwood area by creeping, for example the remaining 5 mm). [DE BAT study 2013]

The filling level of the impregnating boiler must be reduced due to the increased formation of foam resulting from the application of chromium-free wood preservatives in Plant DE-3 (approximately 0.5 m less filling). In addition, it has to be checked that there are no dry spots on the top edges of the impregnation boiler (due to the lower filling level, the wood preservative does not reach the wood) and that the wood is completely impregnated. The filling level of the impregnation boiler has to be precisely set in advance of the impregnation process and the

impregnation boiler capacity can be exploited to a slightly lesser degree (reduced production capacity, see sketch below). [DE BAT study 2013]



**Figure 15.29: Reduction of filling level (example plant DE-3)**

#### **Cross-media effects**

Lower degree of capacity utilisation in the installation through reduced filling level of the impregnating boiler. In the case of dry area formation, the wood must be repeatedly treated.

After service life, the impregnated wood products can be incinerated for energy use in an appropriate combustion plant. Chrome-free wood preservative induces chromium-free incineration ash. [DE BAT study 2013]

#### **Technical considerations relevant to applicability**

For the vacuum pressure impregnation, there are generally no restrictions for the application of chromium-free preservatives. The following aspects have to be *inter alia* respected:

- increased, partly strong foaming;
- accurate adjustment of the process parameters and necessity for additional control measures/instruments;
- lower filling level and thus lower production capacity;
- application of vacuum must be used at different location, if necessary;
- corrosion or incrustations may occur.

The constraints cannot be excluded by application of other impregnation processes, e.g. by alternating pressure process there is strong formation of foam. In this case, a precise selection of the adequate impregnating agent and impregnation process is required (for example, in collaboration with the wood preservative manufacturer). [DE BAT study 2013]

#### **Economics**

The chromium-free preservative is about 30 % more expensive. Only low levels of investment are required for the system adaptation (vacuum pressure impregnation) which usually does not go significantly beyond the normal operating expenses (e.g. substitution of oil-cooled pumps with water-cooled pumps due to foam formation; replacement of corroded/encrusted lines/seal). [DE BAT study 2013]

#### **Driving force for application**

Requirements under the Biocidal Product Directive [DE BAT study 2013]

#### **Example installation**

Plant DE-3.

**Reference literature** No information submitted.

### 15.4.3.1.2 Recirculation of water or wood preservative solution containing spills, drips or condensates to preservative mixture (closed circuit)

#### Description

In treatment plants using water-based wood preservatives, small quantities of liquids may arise and these can be reintroduced into the product mixing system or storage tank provided they do not contain dust or wood-based particles. Ideally the liquid should be filtered to remove these undesirable materials.

#### Technical description

In treatment plants using water-based wood preservatives, small quantities of liquids may arise and these can be reintroduced into the product mixing system or storage tank provided they do not contain dust or wood-based particles. Ideally the liquid should be filtered to remove these undesirable materials.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

#### Technical considerations relevant to applicability

In the case of creosote or light-organic-solvent-based wood preservatives, it is not possible to recirculate water contaminated with preservative back into the product and such liquids have to be collected and disposed of according to hazardous waste legislation.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

### 15.4.3.2 Solvent-based preservatives

#### 15.4.3.2.1 Concentrated biocides systems

*(Information from 2007 STS BREF, TWG is kindly asked to provide information (10 heading structure for BAT candidates), if it considers this technique applicable to WPC sectors.)*

#### Description

Solvent-based solutions with a higher concentration of pesticides-biocides can be used.

#### Technical description

#### Achieved environmental benefits

There is a higher application rate for the same amount of solvent and energy used in process cycles. See Table 15.18: ~~Table 18.1~~

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** See Table 15.18: ~~Table 18.1~~  
No information submitted.

**Driving force for implementation** SED

**Example plants** No information submitted.

**Reference literature** [140, EDTEI, 2005]



**15.4.3.2.2 Use of solvents with a lower photochemical ozone creation potential**

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.  
**Example plants** No information submitted.  
**Reference literature** No information submitted.

**15.4.3.2.3 Solvent recovery from waste gas and recycling system**

**Description** No information submitted.  
**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: none.

**Reference literature** No information submitted.

**15.4.3.2.4 18.4.4 Waste gas treatment****Description**

Emissions can be reduced by ~~applying a solvent management plan (see Section 20.3.1), enclosing the process wherever possible so that air can be extracted through abatement equipment (see Section 15.3.3.4.1 18.3.3 above) and using alternative low solvent coatings (see Section 18.4.2.3).~~ The extracted waste gases can be treated. Section 17.10-20.11 describes different waste gas treatment techniques which can be applied.

**Technical description** No information submitted.

**Achieved environmental benefits**

A 70 % reduction of emissions can be achieved with these measures.

**Environmental performance and operational data**

The EGTEI data discuss the use of two types of waste gas treatment: thermal oxidation, adsorption with solvent recovery. It is not clear if recovery here means on- or off-site. Adsorption on cartridges with off-site recovery or disposal may also be considered.

**Cross-media effects**

No data submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics**

In large wood preservation plants, treatment of emissions is carried out. In smaller plants, abatement equipment may not be economically viable. See Table 15.18 48-1. Solvent absorption with either off-site recovery or disposal of absorption cartridges may be the most viable option.

**Driving force for implementation:** SED.

**Example plants** No information submitted.

**Reference literature:** [108, DFIU/IFARE, 1999] [109, European Environmental Agency, 2001] [140, EGTEI, 2005]

### 15.4.3.3 Creosote

#### 15.4.3.3.1 Use of low-emission impregnating oils / Grade C creosote

##### **Description**

Substitution of Grade B creosote with Grade C creosote.

##### **Technical description**

The impregnation process is changed from impregnation with Grade B creosote to Grade C creosote.

##### **Achieved environmental benefits**

Reduced emission of volatile organic compounds (VOCs) and odour.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

##### **Example plants**

Plants applying BAT candidate: DE-5, DE-9, DE-8, SNCF, Track, C&G,

**Reference literature** No information submitted.

#### 15.4.3.3.2 Use of 'low-emission' impregnating oils / Mixture with partial substitution of creosote

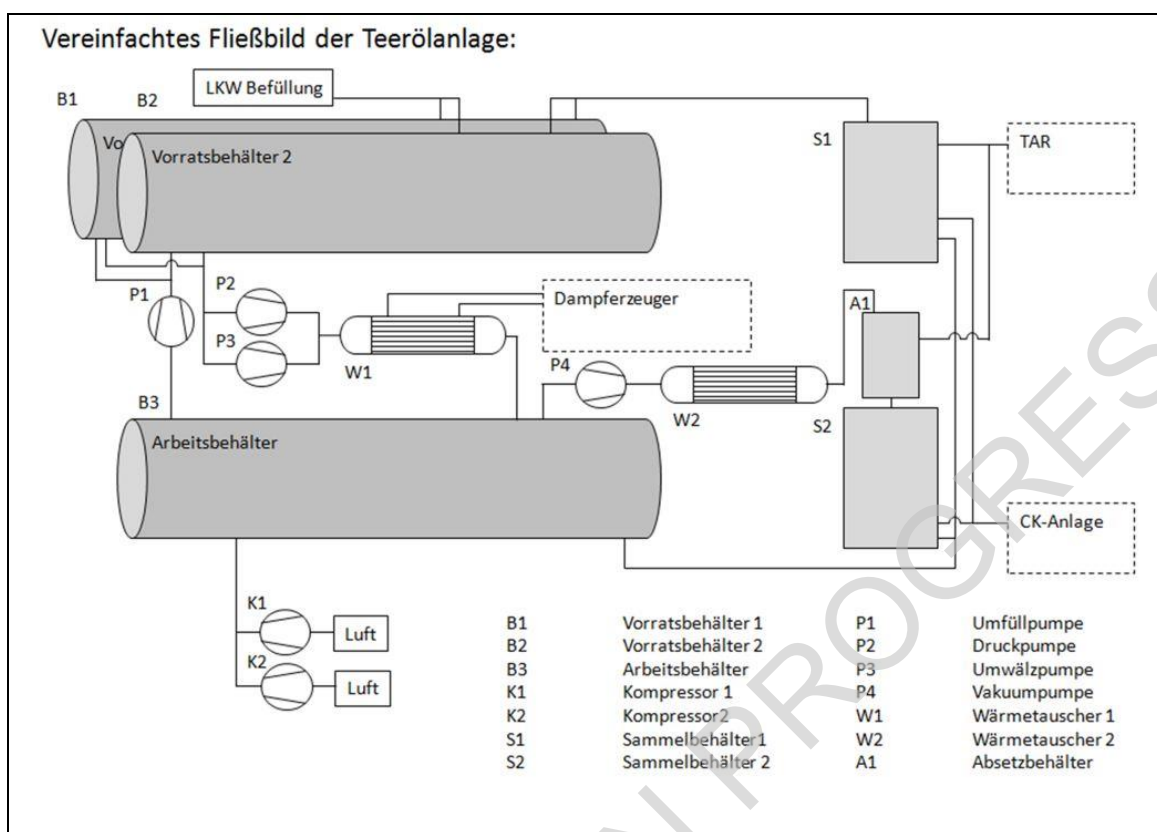
##### **Description**

Creosote is partially replaced by other substances, e.g. linseed oil, biocides and other auxiliary substances.

##### **Technical description**

The impregnation with IWW - Woodcare has a similar effect to coal tar oil, but with a lower environmental impact. IWW - Woodcare is an emulsion concentrate for the impregnation of wood in the boiler pressure process at 8–10 bar at normal temperature (for example for wood thresholds, wooden masts, timber). It can be used in conventional KVD systems (such as aqueous protective salt solutions).

- 70 parts of coal tar type WEI B or type.
- 20 parts modified linseed oil Co-emulsifier and binder (fixative).
- 10 parts of N, N-didecyl-N-methylpoly (oxethyl) ammonium propionate, co-biocide and emulsion stabiliser. [DE BAT study 2013]



**Figure 15.30: Schematic of a plant partially substituting creosote with an emulsion**

*Labels in the figure will be translated to English for final figure inserted in BREF.*

#### Achieved environmental benefits

- Reduction of environmental pollution (e.g. avoiding odour pollution, lower tar oil contamination).
- Reduction of energy consumption since no heating of the impregnating agent is necessary. [DE BAT study 2013]

#### Environmental performance and operational data

The main advantages highlighted by the manufacturer are:

- low dose, high effect;
- favourable toxicological profile;
- low environmental impact;
- significantly reduced smell of treated wood;
- no surface stickiness of treated wood (no bleeding and sweating);
- slight colour influence on treated wood;
- processability in conventional KVD systems (such as aqueous protective salt solutions);
- processing without heating the impregnating agent, less energy expenditure;
- good basis for any colour surface design;
- high efficacy against wood-destroying insects, including termites, fungi and faeces;
- facilitated disposal of treated wood in suitable plants, as metal- and halogen-free;
- IWW-Woodcare is not corrosive;
- good and uniform penetration in the wood;
- fixation within a few hours. [DE BAT study 2013]

#### Cross-media effects

None.

#### Technical considerations relevant to applicability

Modification and adaptation of the existing plant [DE BAT study 2013]

**Economics**

The costs are comparable with conventional impregnation processes. [DE BAT study 2013]

**Driving force for implementation** No information submitted.

**Example plants**

**Reference literature** No information submitted.

**15.4.3.3.3 Collection and treatment of condensates from depressurisation of treatment vessel and vacuum periods and from creosote reconditioning**

**Description**

Condensates are collected, allowed to settle and treated in an activated carbon filter. The water so treated is either reused (closed circuit) or discharged into the public sewer system. [VDI 3462 draft 2014], [DE BAT study 2013]

**Technical description**

In pressure treatment plants using impregnating oils (creosote), waste water streams are generated in form of condensates during depressurisation of the treatment vessel and during the vacuum periods. These condensates are collected, allowed to settle and treated in an activated carbon filter. The water so treated is either reused (closed circuit) or discharged into the public sewer system. [VDI 3462 draft 2014], [DE BAT study 2013]

Process condensates occurring during the ‘creosote conditioning phase’ prior to the treatment process can be collected and treated the same way as condensates from the vacuum/depressurisation phase of autoclaves.

Designs may vary, but control techniques usually include closed loop and secure systems with condensate return system within the installation boundary. Condensate/water may be boiled and vapour recovered and disposed of via high-temperature (>850 °C) or vapour scrubbing systems. [OES auto 2016]

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants**

Plants applying BAT candidate: DE-5, DE-8, SNCF, Track, C&G (collecting from depressurisation of treatment vessel and vacuum periods)

**Reference literature** No information submitted.

**15.4.3.3.4 Treatment of waste water from creosote processes**

**Description**

Condensates (e.g. from droplet separators) are contaminated and have to be treated (internal or external) or disposed of as liquid waste. Treated waste water can be recirculated if water-soluble salt concentrates or emulsions are used on site. If waste water treatment is done on site it consists of a storage tank, flotation, and chemical treatment/precipitation.

Waste gas from waste water treatment is cleaned, e.g. with activated carbon. For this propose, waste gas from waste water treatment can be combined with waste gas from creosote processing and both streams can be treated together.

**Technical description** No information submitted.  
**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

**Example plants** No information submitted.  
 Plants applying BAT candidate: DE-5, DE-8, SNCF, C&G

**Reference literature** No information submitted.

#### 15.4.3.3.5 Vapour emission control for creosote (re)conditioning area

##### Description

Enclosure of the creosote (re)conditioning area with off-gas extraction and treatment by activated carbon or thermal oxidiser.

##### Technical description

Enclosure of the creosote (re)conditioning area with off-gas extraction and treatment by activated carbon or thermal oxidiser.

Vapour emissions from this process are connected to the condensate collection system [OES auto 2016]

**Achieved environmental benefits** No information submitted.  
**Environmental performance and operational data** No information submitted.  
**Cross-media effects** No information submitted.  
**Technical considerations relevant to applicability** No information submitted.  
**Economics** No information submitted.  
**Driving force for implementation** No information submitted.

**Example plants**  
 Plants applying BAT candidate: DE-5, SNCF, C&G

**Reference literature** No information submitted.

#### 15.4.3.3.6 Exhaust gas capture for hot-cold bath creosote treatment (plus gas extraction and emission abatement system)

##### Description

Enclosure with doors to open for loading/unloading is installed covering the impregnation trough and capturing emissions during the whole treatment process: impregnation, lifting of charge and cooling.

Emissions are extracted until the timber has cooled to ambient temperature. The off-gases are directed to an air pollution control device, e.g. an exhaust gas scrubber or activated coal filter.

##### Technical description

During the impregnation process and cooling stage, the hot-cold bath treatment tank is closed by a moveable top cover and waste gas is collected from the closed tank for further treatment (e.g. scrubber). [DE BAT study 2013]

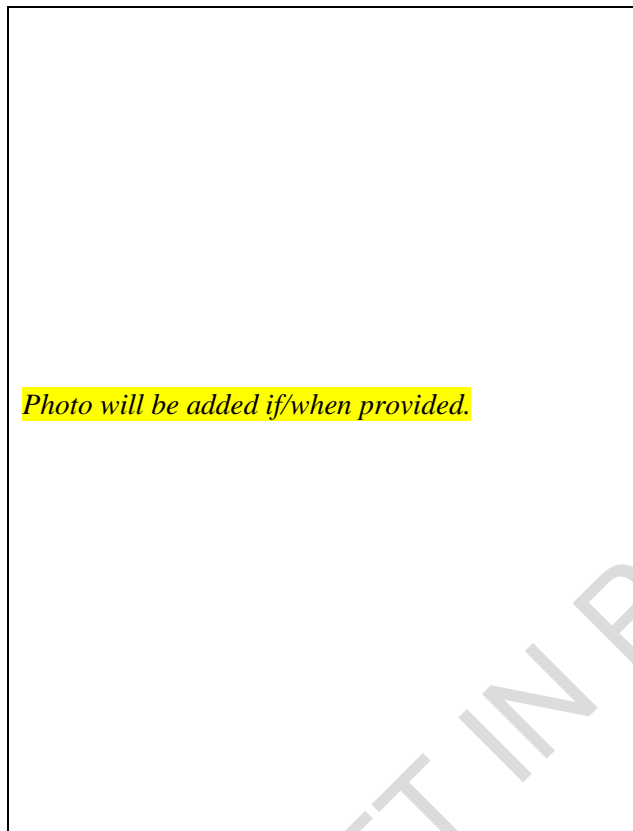


Figure 15.31: Enclosure installed at a hot-cold bath creosote treatment plant (open for discharging of treated wood)

The extracted emissions are abated by a scrubber, see Figure 15.32.

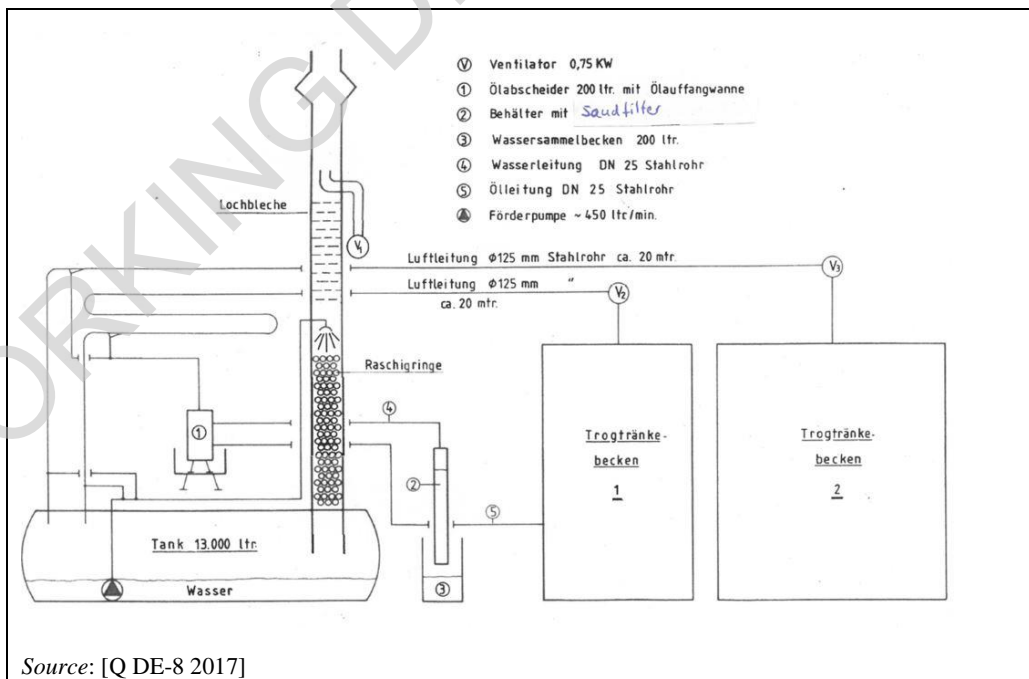


Figure 15.32: Schematic of the emission abatement system (scrubber) installed at a hot-cold bath creosote treatment plant

**Achieved environmental benefits**

Reduction/capture of diffuse emissions.

Reduction of emissions to air, especially VOC and PAH.

**Environmental performance and operational data** No information submitted.**Table 15.26: Reported emission levels for a creosote plant with hot-cold bath treatment quipped with a scrubber**

Parameter	Achieved emission level				
	Waste gas flow (Nm <sup>3</sup> /h)	TOC (mg C/Nm <sup>3</sup> )	PAH (mg/Nm <sup>3</sup> )	Naphthalene (mg/Nm <sup>3</sup> )	Benzo(a) pyrene
Year of measurement: 2006					
Average value (of samples taken during the monitoring exercise)	1260		0.198 <sup>(1)</sup>		< LoD (LoD: 0.05µg/m <sup>3</sup> )
Duration of monitoring exercise (h)					
Number of samples/measurements per monitoring exercise			2		2
Abatement efficiency (%)					
Year of measurement: 1997					
Average value (of samples taken during the monitoring exercise)		3.9*	1.38	1.21	< LoD (LoD: 0.002 mg/m <sup>3</sup> )
Duration of monitoring exercise (h)		0.5	0.5	0.5	0.5
Number of samples/measurements per monitoring exercise		1	1	1	1
Abatement efficiency (%)		98.7**	97.9**	97.9**	
* Calculated, 1- and 2-Methylnaphthalene included. ** Simultaneous measurements of raw and clean gas. <sup>(1)</sup> Individual PAH values of the samples taken during the monitoring exercise: 0.192 and 0.204 mg/Nm <sup>3</sup> . Source: [Q DE-8 2017]					

**Cross-media effects** No information submitted.**Technical considerations relevant to applicability** No information submitted.**Economics** No information submitted.**Driving force for implementation** No information submitted.**Example plants** No information submitted.**Reference literature** No information submitted.**15.4.3.3.7 Enclosure of creosote pressure treatment****Description****Technical description**

During the impregnation process, air is displaced from the impregnation, preheating and storage vessels. This air is contaminated and has to be collected and treated with a waste gas abatement technique.

To reduce fugitive emissions, the area around the opening of the impregnation vessels can also be covered by an enclosure (building). During and after the opening of the vessels, the waste gas is collected at the top of the enclosure and treated in a waste gas abatement system. If the opening of the vessels is enclosed, there must be a possibility to open the vessels from the outside of the enclosure, because of occupational health and safety reasons. Furthermore, enclosure (building) of the working area with slight negative pressure (waste gas to abatement system) can reduce fugitive air emissions.

### Achieved environmental benefits

Reduction of emissions

### Environmental performance and operational data

The emission data provided for a German creosote plant during the WPC data collection in 2017 is summarised in

Table 15.27.

**Table 15.27: Reported emission levels for creosote pressure treatment plant equipped with adsorption**

Measured parameter	Waste gas flow (Nm <sup>3</sup> /h)	TOC (mg C/Nm <sup>3</sup> )	CMR (mg/Nm <sup>3</sup> )	Naphthalene (mg/Nm <sup>3</sup> )	Benzene (mg/Nm <sup>3</sup> )	Benzo (a) pyrene (mg/m <sup>3</sup> )	Phenole (mg/m <sup>3</sup> )
Average value	<b>4480</b>	<b>3.1</b>	<b>0.00034</b>	<b>&lt; 1.91</b>	<b>&lt; 0.06</b>	<b>0.000004</b>	<b>&lt; 0.032</b>
Duration of monitoring exercise (h)	4	4	4	4	4	4	4
Number of samples/measurements per monitoring exercise	8	8	8	8	8	8	8
Additional information on monitoring or measurements:	-	max 6.9	max 0.0014	-	-	max 0.000005	max <0.055
Monitoring standard/method		EN 12619:2013	<i>DIN EN 13649/ VDI 3874 sampling</i>	<i>DIN EN 13649 / VDI 3874 sampling</i>	<i>DIN EN 13649</i>	VDI 3874 sampling	VDI 3874 sampling
Uncertainty of a single measurement (%)	10	-	-	-	-	-	-
Uncertainty subtracted from the reported values?	No	No	No	No	No	No	No
Year of measurement 2015 [Q DE-5 2017].							

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.



#### 15.4.3.3.8 Thermal oxidation

*(Text as provided, editing will be done at a later stage)*

##### **Description**

Process gas from the coal-tar oil impregnation tanks is fed to a thermal oxidiser. Organic components in the process gas are oxidised with natural gas at a temperature of 750 °C.

Exhaust gases generated from the tanks of the creosote-impregnating installation are fed into the thermal oxidation (see VDI 2442). Organic components in the exhaust gas are burned. The thermal oxidiser performs the process of oxidation of flammable gases and aromatic substances in the exhaust gas where the mixture of air or oxygen with pollutants is heated with natural gas in a combustion chamber long enough to be above the auto-ignition point in order to reach the nearly complete combustion to CO<sub>2</sub> and water. [DE BAT study 2013]

##### **Technical description**

###### ***Example DE-1 (mixed: WB and C plant)***

The thermal oxidation works with natural gas at a temperature of 750 °C. The hot exhaust gas is used to pre-heat the combustion air, as well as to heat water to 80 °C to produce steam for the steam generator. The thermal oxidiser is only in operation when the process gas is displaced or extracted by suction from the tanks of the creosote production line. For this purpose the system is heated to 750 °C for 15 minutes. The process gas is blown into the system for 15 minutes. In another 15 minutes the temperature is controlled and stepwise reduced, to avoid too rapid cooling. The supply pipe for process gas to be oxidised is equipped with a fire safety device.

The ventilation for the burner has a performance of 0.76 kW and the exhaust fan has a capacity of 7.5 kW. Accumulated hot water from the heat exchanger of the thermal oxidation is with a condenser pump (0.46 kW) returned in the steam cycle system and heated to 80 °C in the thermal post-combustion. The exhaust gas of the thermal oxidation is inspected in regular intervals (measurement according to § 28 BImSchG).

##### **Achieved environmental benefits**

Reduction of emissions to air (volatile organic compounds (VOCs) from creosote treatment).

##### **Environmental performance and operational data**

The values in Table 15.28 come from a typical measurement protocol (normal operating conditions, presentable for the thermal oxidation, mass concentration, related to dry exhaust gas, standard condition, 273 K, 1013 hPA, no reference oxygen set, measuring accuracy: ±5 %). [DE BAT study 2013]

**Table 15.28: Reported emission values after thermal oxidation in the creosote (coal tar oil) impregnation installation plant DE 1**

Parameter	Half hour average values	Limit values (operating permit)	Sampling point	Measurement procedure
CO	49 mg/m <sup>3</sup>	100 mg/m <sup>3</sup>	The sampling point is located directly in front of the fan in the exhaust duct*	in accordance with VDI 2459, part 6
NO <sub>x</sub>	104 mg/m <sup>3</sup>	200 mg/m <sup>3</sup>		in accordance with VDI 2456, part 9
Total C	14 mg/m <sup>3</sup>	50 mg/m <sup>3</sup>		VDI 3481, part 1 und EN 12619
Benzo[a]pyrene	< 0.002 mg/m <sup>3</sup>	0.1 mg/m <sup>3</sup>		Sampling in accordance with DIN EN 1948 and analysis according to VDI 3873, part 1
<p>* The sampling point is not the recommendation of the VDI 2066 part 1. For practical reasons, inlet and outlet conditions are not respected. The results obtained are representative in the sense of no. 5.3.2.2 TA Luft of 24.07.2002. A plausibility check is given in the measurement protocol.</p> <p>Source:[DE BAT study 2013]</p>				

The total exhaust gas volume amounts to 500 000 m<sup>3</sup> per year. On the basis of specified concentrations, this corresponds to annual pollution load of 24.5 kg/year of CO, 52 kg/year of NO<sub>x</sub>, 7 kg/year of total carbon and less than 0.001 kg of benzo[a]pyrene. Emissions occur discontinuously as the thermal exhaust gas cleaning is only operated temporarily. The annual pollution loads are in the range of the hourly values of the Technical Instructions on Air Quality Control (TA Luft) for benzo(a)pyrene and oxides of nitrogen (see point 4.6.1.1 TA Luft; for oxides of nitrogen = 20 kg/h; = 0.0025 kg/h for benzo(a)pyrene). [DE BAT study 2013]

Natural gas consumption: 1 440 000 kWh/year for thermal exhaust gas cleaning and associated steam generation (to the heat supply for the impregnation processes in the system).

Cleaning performance of the thermal oxidiser approximately 500 000 m<sup>3</sup>/year. [DE BAT study 2013]

**Table 15.29: Reported emission levels for creosote pressure treatment plants equipped with thermal oxidisers**

Parameter	Achieved emission level (O <sub>2</sub> level =12%)					
	Waste gas flow (Nm <sup>3</sup> /h)	TOC (mg C/Nm <sup>3</sup> )	PAH (mg/Nm <sup>3</sup> )	PCDD (mg/Nm <sup>3</sup> )	NO <sub>x</sub> (mg/Nm <sup>3</sup> )	CO (mg/Nm <sup>3</sup> )
<b>Plant: DE-9 (measurement 2016)</b>						
Average value	<b>1723</b>	<b>9</b>	-	-	<b>98</b>	<b>444</b>
Duration of monitoring exercise (h)	1.5	1.5	-	-	1.5	1.5
Number of samples	3	3	-	-	3	3
Monitoring standard/method	ISO 10780 and VDI 2066 Bl. 1	EN 12619:2013	-	-	DIN 33962	EN 15058:2006
Uncertainty of a single measurement:	-	2.3g/m <sup>3</sup> EN 12619 and VDI 3481 B14	-	-	0.002 g/m <sup>3</sup> DIN 33962	0.007 g/m <sup>3</sup>
<b>Plant: Octo (measurement 2014, NO<sub>x</sub>/CO additional 2016 and 2015)</b>						
Average value	<b>10700</b>	<b>0.8</b>	<b>0.8</b>	<b>0</b>	<b>678</b> 538 469	<b>459</b> 315 361
Duration of monitoring exercise (h)	24	24	24	24	8776	8776
Number of samples	1	1	1	1	continuous	continuous
Monitoring standard/method	-	-	-	-	-	-
Uncertainty of a single measurement (%)	5	5	7	6	-	-
Uncertainty subtracted from the reported values?	yes	yes	yes	yes	-	-
<i>Source: [Q DE-9 2017], [Q Octo 2017]</i>						

**Cross-media effects**

Energy use for the thermal oxidiser (CO<sub>2</sub> emissions; use of natural gas). [DE BAT study 2013]

**Technical considerations relevant to applicability**

Applicable only in the case of the coal tar oils impregnation process.

**Economics**

- Investment costs: no data submitted.
- Operating costs: cost for a not specified share of 1 440 000 kWh/year of natural gas.
- Personnel costs for the operation, maintenance and technical certification. Specific costs are not available. [DE BAT study 2013]

**Driving force for application**

Legal requirements (operating permit, TA Luft 2002).

**Example installation**

Installation DE 1.

**Reference literature**

BREF document, for example. [BREF STS 2007] Chapter 20.11.4.2, [BREF CWW 2011] (Draft) Chapter 4.12.2 (Thermal oxidation), Measurement protocol

**15.4.3.3.9 Thermal treatment of waste gases in a combustion plants (e.g. waste wood biomass boiler)**

**Description**

Extracted waste gases are burned in available combustion facilities used for the production of steam for heating creosote or steam fixation etc. on site.

**Technical description**

**Example C&G: Combustion in clean waste wood biomass boiler**

The installation incorporates a wood-fired boiler which burns untreated offcuts and process wastes. However, as part of site improvement plans, this is to be replaced with a new modern and energy-efficient 2MW biomass boiler within the first year of this permit's issue. This similarly burns clean wood waste only arising from the installation. It is to provide power and heat and in addition is designed to take emissions from the creosote impregnation processes and thermally treat them in the secondary combustion chamber of the appliance, significantly reducing potential odour emissions and residual VOCs to the environment. [Q C&G 2017]

**Achieved environmental benefits**

Reduction of emissions to air (volatile organic compounds (VOCs) from creosote treatment).

**Environmental performance and operational data**

**Table 15.30: Reported emission levels for creosote pressure treatment plant applying combustion in clean waste wood biomass boiler**

Measured parameter	Waste gas flow (Nm <sup>3</sup> /h)	Total VOC (mg/Nm <sup>3</sup> )	PAH (including naphthalene) (mg/Nm <sup>3</sup> )
Average value (of samples taken during the monitoring exercise)	NI	<b>176.1</b> (2016) <b>144.2</b> (2015) <b>258.1</b> (2014)	<b>11.1</b> (2016) <b>3.73</b> (2015) <b>&lt; 0.12</b> (2014)
Duration of monitoring exercise (h)	NI	<b>6</b>	<b>1.5</b>
Number of samples/measurements per monitoring exercise	NI	<b>2</b>	<b>2</b>
O <sub>2</sub> level (%)	NI	NI	NI
Monitoring standard/method	NI	NI	NI
Uncertainty of a single measurement (%)	NI	NI	NI
Uncertainty subtracted from the reported values?	NI	NI	NI
Abatement efficiency (%)	NI	NI	NI
How was the abatement efficiency defined?	NI	NI	NI
<i>Source: [Q C&amp;G 2017]</i>			

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability**

Applicable to solvent-based treatment and creosote plants.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

**15.4.3.3.10 Activated carbon filtering**

**Description**

Exhaust gas from the tanks of the creosote impregnation is fed to an activated carbon filtering. Organic components are removed from the exhaust gas.

**Technical description** No information submitted.

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

15.4.3.3.11 Closed cooling systems for cooling water

**Description**

No information submitted.

**Technical description**

*(Technique proposed as BAT by Nordic council in [Norden BAT study 2014], but no information (10 heading structure for BAT candidates) provided.*

Cooling systems within creosote installations are generally connected to vacuum process equipment. The cooling medium may include water via heat exchangers, creosote or light oils which may be used to seal 'liquid ring' vacuum systems. [OES auto 2016]

**Achieved environmental benefits** No information submitted.

**Environmental performance and operational data** No information submitted.

**Cross-media effects** No information submitted.

**Technical considerations relevant to applicability** No information submitted.

**Economics** No information submitted.

**Driving force for implementation** No information submitted.

**Example plants** No information submitted.

**Reference literature** No information submitted.

WORKING DRAFT IN PROGRESS

## 16 ADDITIONAL SECTORS

This section contains information for the two following STS sectors not covered by the data collection exercise.

### 16.1 MANUFACTURE OF MIRRORS

[25, GEPVP, et al., 2004]

#### 16.1.1 General information on the manufacture of mirrors

*Needs updating for figures, size of market, number of countries, etc.*

The main production of mirrors is usually carried out by large multinational corporations in plants with capacities of more than 2 million m<sup>2</sup>/yr. The major facilities are situated in Germany, France, Spain, Italy, Belgium, Poland, the United Kingdom, Luxembourg and the Czech Republic. There are also some small producers.

The total demand for mirrors in Europe is estimated as 40 million m<sup>2</sup>/yr. This leads to an annual consumption range of solvents of approximately 2 000–3 600 tonnes. The general applications of mirrors in Europe are:

- mirrors for bathrooms;
- mirrors for furniture;
- architectural uses, e.g. wall covering;
- automotive applications.

The specific consumption, i.e. hourly, of each installation is dependent on the surface of the mirrors produced. The largest lines can produce mirrors of 6 m by 3.2 m, i.e. 19 m<sup>2</sup>. As mirror production is a continuous process, the speed of the line also affects the hourly consumption rates. Thus, some lines exceed the annual and hourly consumption threshold, whilst others only exceed the annual threshold.

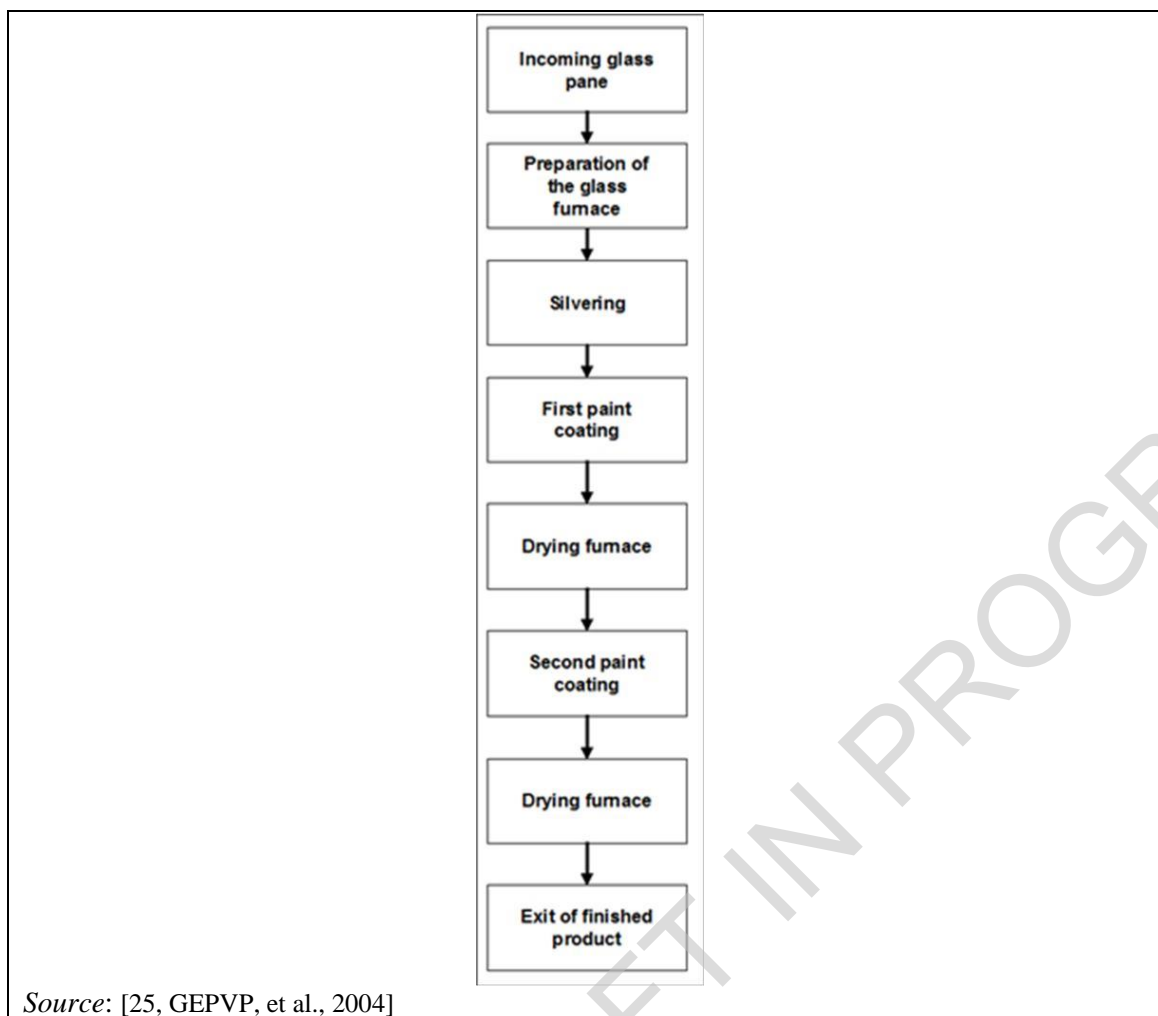
It is estimated that the number of lines that exist in Europe are between 15 and 20. Normally, the number of employees occupied in a mirror line is low, though most lines are part of a large manufacturing company.

#### 16.1.2 Applied processes and techniques in the manufacture of mirrors

The production line is designed as a continuous process. The glass sheet lies on a large conveyor that leads the mirror through the different steps of manufacturing. Conveyors are up to 3.5 m wide and more than 150 m long to allow the manufacturing of large scale mirrors. Typically, mirrors consist of one glass pane covered by a reflective metallic layer which is protected by one or more paint coatings. After the paint coating, the mirror passes through the drying furnace.

*Source:* [25, GEPVP, et al., 2004]

Figure 16.1 summarises the different steps in the manufacture of mirrors. These are described in detail in the following sections.



**Figure 16.1: Flow chart of the manufacture of mirrors**

### 16.1.2.1 Incoming glass pane

Glass is usually fed to the mirror factory by lorries. The glass is then stocked on stillages and unloaded onto the mirror line using vacuum lifting devices. No solvent is used at this stage.

### 16.1.2.2 Preparation of the glass surface

The preparation of the glass surface consists of a slight polishing using a water-based abrasive slurry containing cerium salts. No solvent is used at this stage. The waste water is treated and the sludge recovered for disposal.

### 16.1.2.3 Silvering

The reflective metallic layer is generally made of silver, which is sensitive to corrosion and therefore protected by the paint layer which follows. A description of a silvering process and control of emissions of silver, tin, and palladium can be found in the STM BREF [59, EIPPCB, 2006]. Currently, most producers use the tin process instead of the copper process for fixing the silver layer. No solvent is used at this stage. Aluminium is also used for the reflective metallic layer.



#### 16.1.2.4 Paint coating

The glass is passed through a laminar curtain of paint, which is continuously falling from a trough-type assembly. The excess coating material is permanently reused, but extra solvent is added to ensure proper application viscosity. The paint used is solvent-based and contains 30–40 wt-% solvent. The paint consumption ranges from 150 g/m<sup>2</sup> to 200 g/m<sup>2</sup>. The total thickness of the dried paint coating(s) is in the range of 40 µm to 70 µm.

#### 16.1.2.5 Drying

After the paint coating, the mirror is taken to the drying furnace where the solvent is evaporated and the paint dried allowing its polymerisation. Drying is promoted by heating the product by infrared radiation with or without convection heat.

#### 16.1.2.6 Exit of the finished product

At the end of the line, the mirror is unloaded by using vacuum lifting devices and stacked on stillages. No solvent is used at this stage.

### 16.1.3 Current consumption and emission levels in the manufacture of mirrors

[As a small number plants above the IED capacity threshold was identified, it was decided not to collect data through questionnaires. The following sections are the same as in the original STS BREF (2007)]

#### 16.1.3.1 Mass balances

No data submitted.

#### 16.1.3.2 Consumptions

##### 16.1.3.2.1 Materials

The total solvent consumed amounts to 50–90 g/m<sup>2</sup>, depending on the type of product manufactured. Also, some solvent is used for cleaning. The solvent used is xylene.

The greatest proportion of the solvent is used to adjust the paint viscosity and applied onto the product. A small amount is used for cleaning purposes, i.e. <10 %. When this solvent is not contaminated, it is added to the solvent used to adjust the paint viscosity.

Normally, it is expected that 100 % of the glass used as input is transformed into mirror. Only accidental losses of glass may occur (e.g. due to quality problems). In most instances, the rejected glass/mirror is recycled.

##### 16.1.3.2.2 Water

The water consumption is in the range of 15 to 30 l/m<sup>2</sup>.

**16.1.3.2.3 Energy**

No data submitted.

**16.1.3.3 Emissions****16.1.3.3.1 Emissions to air**

The solvent content in the clean gas can be reduced to  $<50 \text{ mg C/Nm}^3$  when applying abatement equipment. Lower values can be achieved in new installations. In existing installations, due to the wearing of the mobile parts (e.g. valves), the emission levels increase. The nature of the solvents used can also have an impact on the reduction level that can be achieved. Table 16.1 shows air emission values measured on three different installations.

Line	C (mg/Nm <sup>3</sup> )	CO (mg/Nm <sup>3</sup> )	NO <sub>x</sub> (mg/Nm <sup>3</sup> )
1	57 (range 20 – 100)	65	43
2	16	120	<25
3	55	98	41

**Table 16.1: Air emission values from three different mirror lines**

In a good practice plant, all areas where solvents are used are enclosed and the air containing the solvent is extracted. 97.4 % of the solvent is treated and destroyed. The rest, i.e. 2.6 %, is released to the air because its concentration is too low to be treated.

**16.1.3.3.2 Emissions to water**

Because there is no contact between the water and the solvent anywhere in the process, solvent is not present in the waste water.

Water is used for the surface preparation and the application of the tin (or copper) and silver layer (see the STM BREF). Thus, water treatment is needed to remove contaminants and to ensure the recycling of the silver. Conventional techniques are used, for example, when copper is used instead of tin, ion exchange and ammonia stripping can be used to remove the copper from the waste water. Table 16.2 shows water emission values after treatment.

Compound	Value (mg/l)
NH <sub>3</sub>	100
Ag	0.5
Cu	4
Ce	5

**Table 16.2: Water emission values after treatment**

**16.1.3.3.3 Wastes**

The wastes containing solvents consist mainly of wipes from cleaning and spent solvent containing some paint. Its management and disposal is dictated by its composition and specific measures may be needed due to its solvent content. When it does not contain any contaminants that can alter the quality of the final product, the spent solvent is re-used to adjust the paint viscosity. Re-usable or recyclable paint containers are commonly used in mirror production.

## 16.1.4 Techniques to consider in the determination of BAT for the manufacture of mirrors

[As a small number plants above the IED capacity threshold was identified, it was decided not to collect data through questionnaires. The following sections are the same as in the original STS BREF (2007)]

### 16.1.4.1 General techniques in the manufacture of mirrors

In Chapter 16, techniques are discussed which might also be applicable to mirror manufacturing. In Section 17.7, techniques relevant to paint application are discussed. These techniques might also be applicable to mirror manufacturing. In Table 16.3, the general techniques relevant for mirror manufacturing that are described in Chapter 16 and/or Section 17.7 are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

**Table 16.3: Reference to techniques generally applicable to the sector**

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

### 16.1.4.2 Replacement of conventional solvent-based paints (substitution)

#### 16.1.4.2.1 High-solids paints

For a general description, see Section 17.7.2.1. The mirror industry is already using this type of paint. The solvent content in the paint is between 30 wt-% and 40 wt-%.

### 16.1.4.3 Paint application techniques and equipment

#### 16.1.4.3.1 Curtain coating

##### Description

For a general description, see Section 17.7.3.5. The glass is passed through a laminar curtain of paint continuously falling from a trough-type assembly. This allows the manufacture of large dimension mirrors while ensuring the required quality in equivalence of the layers. The excess coating material is permanently reused, but extra solvent is added to ensure proper application viscosity.

The paint used is solvent-based and contains 30–40 % solvent. Its consumption ranges from 150 g/m<sup>2</sup> to 200 g/m<sup>2</sup>. In the past, paint contained high quantities of lead (up to 15 %). Today, new developments in mirror manufacturing allow the industry to use a low lead content paint (< 0.5 %). No chromate is used in this type of paint.

**Achieved environmental benefits**

No data submitted.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

This technique is widely used in large mirror plants.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[25, GEPVP, et al., 2004]

**16.1.4.4 Drying**

The following techniques are applied:

- infrared radiation curing (see Section 17.8.3.1);
- thermal reactor (see Section 17.8.5.1);
- ultraviolet (UV) curing (see Section 17.8.5.2).

**16.1.4.5 Waste gas treatment**

**Description**

The areas where the paint is mixed and applied onto the mirror are enclosed and equipped with an air extraction system routing the solvent emissions to the waste gas treatment equipment (see Section 17.10.2). Currently, any oxidation technique described in Section 17.10.5 can be applied.

**Achieved environmental benefits**

No data submitted.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

Given the amount of solvent per cubic metre in the flue-gas, many mirror manufacturers use regenerative thermal oxidisers – multiple bed systems (see Sections 17.10.5.4 and 17.10.5.5). As the solvent is mainly xylene, a low burning temperature (750–800 °C) may be applied. Only low levels of NO<sub>x</sub> are formed. Regenerative thermal oxidisers are particularly suited to plants working continuously, i.e. 24 hours a day, 7 days a week. For plants working, e.g. only 8 hours per day and 5 days a week, this technique might be not suitable, as the temperature of the installation must be maintained during the non-working hours. In this case, other oxidising techniques might be more suitable.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plant**

No data submitted.

**Reference literature**

[25, GEPVP, et al., 2004]

## 16.2 MANUFACTURE OF COATED ABRASIVES

[12, UBA Germany, 2002, 38, TWG, 2004] [78, TWG, 2005] [update FEPA/VDS 2016]

### 16.2.1 General information on the abrasives industry

#### 16.2.1.1 Areas of application

Grinding is one of the oldest production processes. A principal characteristic of grinding is the effect of numerous, non-orientated cutting materials in the workpiece. Contemporary abrasive materials are synthetic corundum or silicon carbide often cubic boron nitride (CBN) or diamond.

A large variety of workpiece materials can be processed such as ferrous and non-ferrous metals, glass, ceramics, natural stone, concrete, plastics and wood. The application field of grinding is wide and includes activities such as rough grinding of cast iron or high accuracy grinding of tubular needles for medical purposes. Numerous products in tool manufacturing, construction of vehicles, aircraft, power plants or furniture only obtain their finish and high quality surface through grinding.

#### 16.2.1.2 General information Production and sales

It is estimated that in Europe there are more than 200 companies producing all kinds of abrasives (not only coated abrasives) ~~In Germany, currently more than 100 companies are manufacturing all kinds of abrasives. Therefore, around 70 enterprises are represented by the association of German abrasive manufacturers (VDS – Verband Deutscher Schleifmittelwerke).~~ With a turnover estimated at EUR 3.5 billion and 20 000 work positions in the EU, the abrasives industry is of major importance for the European Union.

It has to be taken into consideration that no installation has been identified that exceeds the criteria (consumption capacity threshold) set in Annex I, point 6.7 of the IED. The following information is based on the information provided for the preparation of the STS BREF published in 2007 and updated with available data. No reference installations are available.

~~According to VDS data, the German abrasive industry plays a leading role in Europe. **Error! Reference source not found.** gives a rough overview of its economical importance.~~

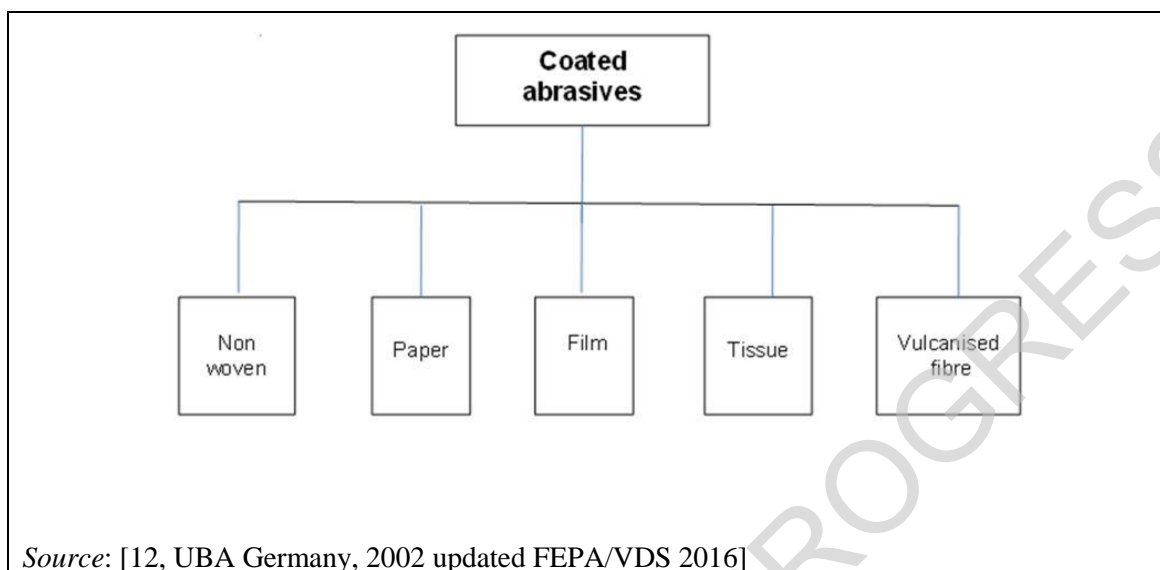
	EUR-million
<b>Production of bonded abrasives</b>	<b>~305</b>
Imports	~82
Exports	~170
<b>Production of coated abrasives</b>	<b>~385</b>
Imports	~205
Exports	~310

Table: Abrasive production in 1999 in Germany  
[12, UBA Germany, 2002]

#### 16.2.1.3 Characterisation of the product 'abrasive' and its quality demands

Basically, the production of abrasives can be distinguished between bonded abrasives, superabrasives, coated abrasives and loose abrasives, which do not have any solid linkage to a backing (e.g. polishing pastes). For this document only the manufacture of coated abrasives is relevant. 'grinding wheels' and coated abrasives 'abrasive paper and tissues'. Loose abrasives exist, which do not have any solid linkage to a backing (e.g. polishing pastes).

Figure 16.2 shows a simplified overview of the different types of coated abrasives on the development and allocation of the different kind of abrasives.



**Figure 16.2: Overview on different types of coated abrasives**

Organic solvents are partially used in the fabrication of bonded and loose abrasives. It can be assumed that European ~~the German~~ installations do not represent an activity in the sense of the IED Annex I point 6.7. ~~IPPC Directive Annex I point 6.7.~~ Consequently, production processes related to these activities will not be mentioned in the following paragraphs.

The activity of manufacturing coated abrasives may be subject to the IED ~~IPPC Directive due to the use of considerable amounts of organic solvents and the threshold limits as set in the Directive.~~ However, in the EU no installation has been identified which exceeds the threshold limits a set in the Directive, Annex I, point 6.7.

Coated abrasives are a basic material for many grinding machines with elements such as blades, stripes, page discs or assembled from those elements (e.g. peel shims, fan grinding wheels, belts). According to the purpose of use and basic material, a large number of bonding systems can be differentiated.

Non-woven abrasives take a special position between coated abrasives and bonded abrasives as they can be both used as an abrasive body as well as an abrasive element. They consist of polyamide fibres, e.g. to which the grinding material is fixed via bonding material. The production processes are comparable to the production of coated abrasives.

Coated abrasives are composed of:

- backing, e.g. paper, finished fabric, vulcanised fibre, film;
- bonding material, e.g. glue systems, phenolic resin, epoxy resin, polyurethane, urea resin;
- abrasive grain, e.g. flint, silicon carbide, corundum, zirconia alumina, seldom used: diamond and CBN.

#### 16.2.1.3.1 Backing

The term ‘coated abrasives’ refers to the importance of the backing. According to the purpose of use and the strain of a flexible abrasive, the backing has to show specific properties. For hand grinding or sanding, special flexibility and high buckling resistance are both required. For high

performance grinding with abrasive belts, abrasive discs and cylindrical sleeves, excellent mechanical properties such as swell-resistance, tenacity, resistance against abrasion or alternating stress, are required.

To meet all these requirements, the following groups of backing materials are particularly used:

- paper;
- film;
- fabric;
- combination of paper/fabric;
- vulcanised fibre.

Table 16.4 shows an example of a classification of the used backing materials:

**Table 16.4: Selected backing materials for coated abrasives**

	Weight class equipped (g/m <sup>2</sup> )
A-paper	≤ 85
B-paper	86–110
C-paper	111–135
D-paper	136–220
E-paper	221–270
F-paper	271–350
G-paper	351–500
H-paper	> 500
A-paper water resistant	≤ 115
C-paper water resistant	> 115
Heavy cotton/X-weight	370–400
Film	100–200
Flexible cotton/J-tissue	270–290
High flexible cotton/J-flex-tissue	200–220
Heavy polyester/X-tissue	475–505
Very heavy polyester/Y-tissue	630–665
<i>Source: [12, UBA Germany, 2002, ; updated FEPA/VDS 2016]</i>	

**Paper**

The papers used in the production of coated abrasives consist of extremely firm and tenacious fibres. They are processed in different qualities, weights, sizes and widths according to the reason for their use. They can be distinguished between:

- flexible;
- single layer paper with a homogenous tensile strength in any direction of straining;
- heavy, multilayer cylinder paper which has an especially high stability in any direction of rolling (long direction).

All types of backings (A to F shown in Table 16.4) are adjusted to dry grinding. A- and C-papers with water resistant preservation (latex or varnish) are appropriate for wet grinding.

Abrasives on A-, B-, and C-papers are used in offhand grinding and for hand operated grinding machines (e.g. a grinding pencil). D- and E-papers are necessary as backings for stationery/fixed grinding machines up to the highest demand.

**Film**

For the production of coated abrasives, films are used which consist of highly tear-resistant plastic. Depending on the intended application, films of different quality, weight, strength and width are processed. Film-based abrasives are mainly used for dry grinding.



**Textile backing**

Textile backing is used for coated abrasives that are processed into wide bands or used in belt, surface and plunge grinding. They consist of fabric as a result of the high strain they are exposed to. These so-called 'technical fabrics' are made of raw cotton (woven or stitch bonded). They can be distinguished between heavy X-tissue and light J-tissue. This differentiation is made due to the thread layer that means the number of fibres used as the warp and weft. Heavy X-tissue has a comparatively low thread count, compared to the light J-tissue.

Before being treated with abrasive grains, the tissue has to be subjected to a special treatment. The raw tissue is first downsized and dyed and afterwards shrunk to its final density. The fabric is finished on its thrust face with adhesives, synthetic resins/plastics or similar substances and finally flattened.

**Vulcanised fibre**

Numerous industrial manufacturing processes require special high performance abrasives with a high wear resistance. In this case, vulcanised fibre is used as backing material. Vulcanised fibre is a very hard, multilayer fibre material. In the course of its fabrication, numerous non-woven-like paper webs are connected through flattening with a contact adhesive. Vulcanised fibre can be manufactured in every thickness. In the abrasive industry, the vulcanised fibre thicknesses of 0.8 mm, 0.6 mm and 0.4 mm are the most important. The wider material is used for high wear resistance and the thinner material for larger flexibility. Abrasives applied mechanically to vulcanised fibre backing have an extremely high resistance to stress. They are applied in almost all industrial branches, e.g. in automotive, machines, ship or apparatus engineering.

**16.2.1.3.2 Bonding material**

The efficiency of coated abrasives depends, to a large extent, on the bond (grain adhesion) of the abrasive grain. Consequently, bonding materials play an important role. In order to achieve a good adhesion of the grain and other required properties, the bonding materials are successively applied in several layers.

The following bonding materials are the most important:

- hide glue;
- synthetic resin;
- varnish.

With consideration of the used bonding agents, the following types of bonding systems are differentiated:

- Glue bond (solvent-free). The bond consists of hide glue and the backing of paper or fabric. These coated abrasives are used for lower shear forces or if the long lasting utilisation of the material is not important (e.g. for the treatment of lubricating materials).
- Partially synthetic resin bond (resin over glue, solvent-free). The abrasive bond system consists of a hide glue make coat and a size coat of synthetic resin. Abrasive papers or fabrics can be used universally, especially for medium grinding operations. Due to the elastic make coat of hide glue and the resistant size coat of synthetic resins, the qualities are very suitable for the surfacing of formed workpieces.
- Synthetic resin bond (solvent-free where possible). Abrasives for high stock removal capacity are bonded with synthetic resins. The abrasive grains are bound exceptionally well to fix to the backing by the comparatively strong resin bond. They are resistant to very high cutting forces. High performance rates can be obtained.
- Varnish, waterproof bond (solvent-based). Numerous workpieces and specific application methods require water-based cooling or rinsing agents. Therefore, the above-mentioned methods cannot be used because either the bonding material or the finishing will be dissolved by the cooling agent. In these cases, totally waterproof tissue qualities are

required. As bonding materials, special synthetic resins are used. Such waterproof abrasives are applied for the wet grinding of steel, glass, ceramics, natural or artificial stone and plastics. For example, when grinding primers, fillers and clear or pigmented lacquers, often clogging or dusty grinding residues result. These load or glaze the abrasive. Therefore, it is necessary to work with waterproof abrasive papers in wet grinding. These papers have a flexible paper backing, which is impregnated with latex or lacquer to make them water resistant. The make- and size coat is made with special resins and lacquers. Waterproof abrasive papers are not only water resistant but also resistant against loading and glazing.

### 16.2.1.3.3 Abrasive grain

For the production of coated abrasives, different types of inert abrasive grains are used. The primary materials used are fused aluminium oxide, silicon carbide and alumina zirconia

- Aluminium oxide:
  - corundum;
  - semi-special fused alumina;
  - special fused alumina rose;
  - special fused alumina red;
  - special fused alumina white;
  - ceramic corundum;
  - zircon corundum.
- Silicon carbide:
  - black SiC;
  - green SiC.

There is a wide range of products based on chemistry, particle size, grain shape and special treatments. For abrasives, particle size is especially carefully controlled in accordance with European Standards (FEPA), American Standards (ANSI), and Japanese Standards (JIS).

#### Aluminium oxide

**Error! Reference source not found.** shows typical values of alumina applied as inert abrasive grain:

	Corundum (%)	Semi special fused alumina (%)	Special fused alumina rose (%)	Special fused alumina red (%)	Special fused alumina white (%)	Ceramic corundum	Zircon corundum (%)
Al <sub>2</sub> O <sub>3</sub>	95.83	97.69	99.52	97.50	99.50	99.6	60.0
ZrO <sub>2</sub>	-	-	-	-	-	-	39.0
SiO <sub>2</sub>	0.60	0.38	-	0.02	0.05	0.07	0.30
TiO <sub>2</sub>	3.12	1.45	-	-	0.02	0.2	0.25
Fe <sub>2</sub> O <sub>3</sub>	0.10	0.15	0.05	0.05	0.05	0.02	0.25
Na <sub>2</sub> O	-	-	0.18	0.3	0.30	0.01	0.03
CaO	0.05	0.03	-	-	0.05	0.01	0.09
MgO	0.20	0.15	-	-	0.01	0.015	0.02
CrO <sub>2</sub>			0.25	2.0			
Others	0.10	0.15	-	0.13	0.02	0.075	0.06
Colour	Dark brown	Light brown	Rose	Ruby red	White	White	Light grey

Table: : Alumina applied as inert abrasive grain (typical values)  
[12, UBA Germany, 2002]

**Silicon carbide**

**Error! Reference source not found.** shows typical values of silicon carbide applied as abrasive grain:

	<b>Black SiC (%)</b>	<b>Green SiC (%)</b>
SiC	98.26	99.66
Free Carbon (C)	0.19	0.29
Fe	0.10	0.02
Si	0.19	0.03
Others	1.26	-

Table: Silicon carbide applied as abrasive grain (typical values) [12, UBA Germany, 2002]

Table 16.5 shows the use of solvent attributed to the different products.

**Table 16.5: Use of solvents in manufacturing attributed to products**

Base	Product	Formed part	Application	Bonding material systems	Solvent
A-Paper	Dry grinding paper	Sheets, rolls	Lacquer and wood grinding (paint)	Hide glue, synthetic resin bond	No
B-Paper	Dry grinding paper	Sheets, rolls	Lacquer and wood grinding (paint)	Hide glue, synthetic resin bond	No
C-Paper	Dry grinding paper	Sheets, rolls, belts	Lacquer, wood and metal grinding (machine)	Partial or complete synthetic resin bond	No
D-Paper	Dry grinding paper	Sheets, rolls, belts	Lacquer, wood and metal grinding (machine)	Partial or complete synthetic resin bond	No
E-Paper	Dry grinding paper	Sheets, rolls, belts	Lacquer, wood and metal grinding (machine)	Partial or complete synthetic resin bond	No
F-Paper	Dry grinding paper	Sheets, rolls, belts	Lacquer, wood and metal grinding (machine)	Partial or complete synthetic resin bond	No
A-Paper waterproof	Wet grinding paper	Sheets	Common grinding of lacquer (hand)	Synthetic resin bond	Yes
C-Paper waterproof	Wet grinding paper	Sheets, belts	Common grinding of lacquer (hand) Machine grinding	Synthetic resin bond	Yes
Film	Dry grinding film	Discs with velcro backing	Grinding of putty, base coats, filler and topcoats	Synthetic resin bond	Partially
X-tissue cotton	Dry grinding; wet grinding	Sheets, rolls, belts	Grinding of metal, glass, wood (machines)	Synthetic resin bond	Partially
J-tissue cotton	Dry grinding	Sheets, rolls, belts	Grinding of metal, glass, wood (machine)	Synthetic resin bond	Partially
J-flex-tissue	Dry grinding	Sheets, rolls, belts	Grinding of metal, glass, wood (machine)	Synthetic resin bond	Partially
X-tissue polyester	Dry grinding; wet grinding	Sheets, rolls, belts	Grinding of metal, glass, wood (machine)	Synthetic resin bond	Partially
Y-tissue polyester	Dry grinding; wet grinding	Sheets, rolls, belts	Grinding of metal, glass, wood (machine)	Synthetic resin bond	Partially

Source: [12, UBA Germany, 2002 updated FEPA/VDS 2016 ]

### 16.2.1.4 Quality requirements

The most important quality criterion is the retaining of the standardised grain size. Toughness, hardness, low dust content, no components of quartz or fibrous parts, and the grain structure are also important. Quality requirements that arise from customers are:

- range of flexibility;
- non-allergenic properties for hand-wet grinding;
- the amount of grains applied to the abrasive for very fine grains.

Due to these requirements, the use of organic solvents is currently necessary in the case of abrasives for wet grinding.

## 16.2.2 Applied processes and techniques in abrasives manufacturing

### 16.2.2.1 Process overview

Coated abrasives are produced in the following way:

- coating of a backing with bonding materials;
- electrostatic or mechanical grain coating as specified in Section 16.2.1.3;
- pre-drying;
- repeated coating with bonding materials;
- drying;
- rolling up into large rolls (jumbo rolls);
- top coating (optional).

Differences in the procedures include the type of drying ovens (festoon dryer or tensionless dryer), the application procedure and the waste gas treatment (biological treatment, thermal combustion or without any treatment).

Solvent coatings are more frequently used in the production of jumbo rolls to self-adhesive products or endless abrasive belts.

Coated abrasives with constant quality are manufactured in production plants with high production levels. Such plants usually consist of the following units:

- base coat part (maker);
- pre-dryer;
- size coat part (sizer);
- dryer;
- spooler.

In the first step, the reverse side of the backing is printed in the so-called 'maker' with the required information (e.g. brand and quality labels). Afterwards, the make coat is applied on the front side of the backing. Then it is coated with abrasive grains. In the second part of the plant – the pre-dryer – hot air dries or hardens the make coat. In the third production unit – the 'sizer' – the backing that is now coated with abrasive grains is furnished with a size coat. In the fourth unit, the hot air heated dryer can be found and the finished abrasive material runs through it for a specific time. After this procedure, the material leaves the plant dried and cured and is rolled up into large rolls (jumbo rolls).

A multitude of electronic and thermal measuring units control the whole procedure and ascertain specific tolerance limits. Among other things, this refers to the grain coating of the backing.

### 16.2.2.2 Detailed process steps

Figure 16.3 shows an overview of a typical plant.

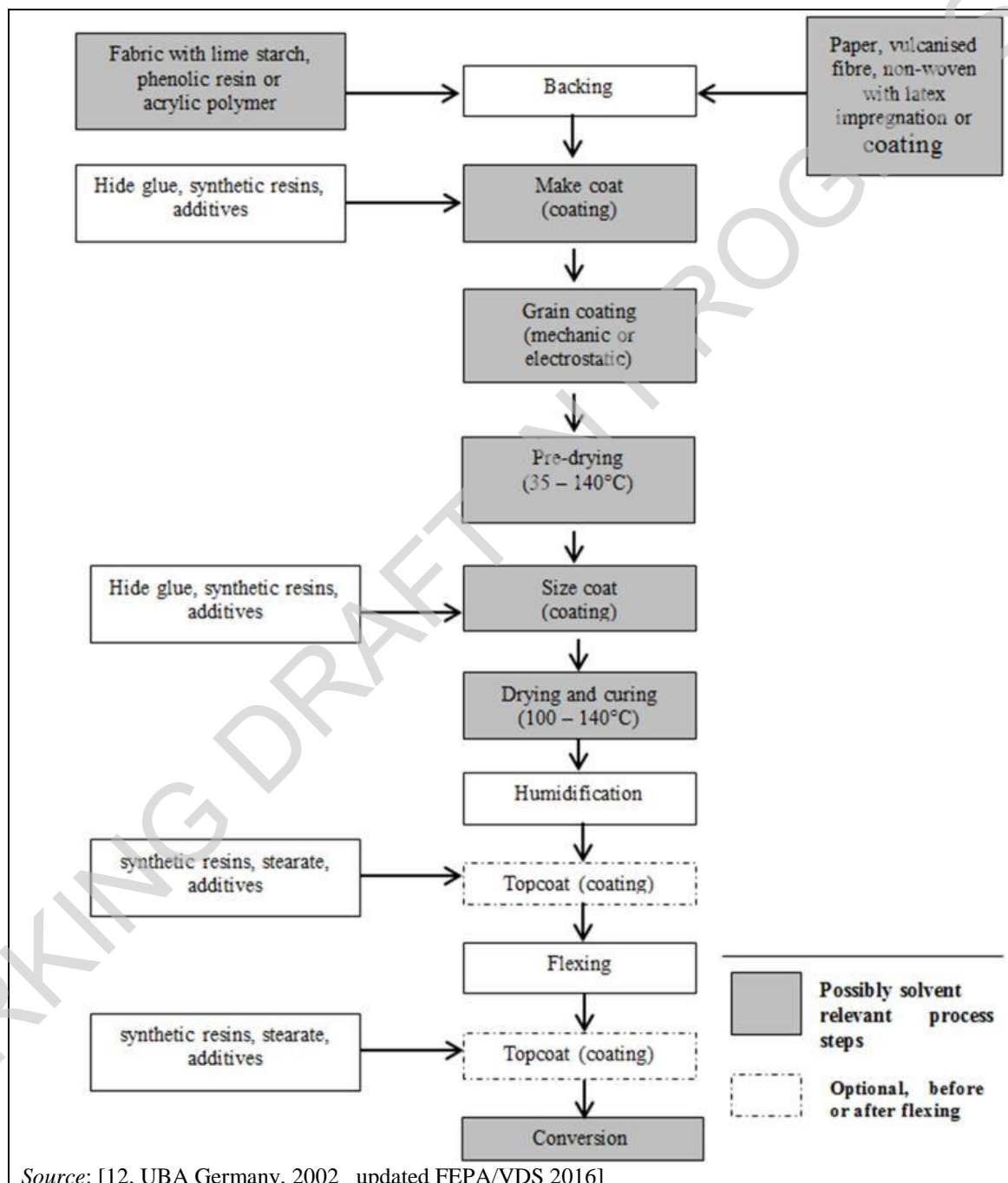


Figure 16.3: Schematic process flow for coated abrasives

### 16.2.2.2.1 Pretreatment of backings

The pretreatment is an optional process step in an abrasive production plant.

#### **Paper**

Depending on the further application of the paper, the pretreatment differs. For example, the backing for waterproof abrasive papers is impregnated with long chain alkyd resins. Latex dispersion sometimes used in combination with water dilutable phenolic resins (for better heat resistance) may be a solvent-free alternative.

#### **Fabrics**

The following fabrics are used as backing:

- cotton;
- synthetic;
- mixed (cotton and synthetic).

The modification of the bonding material for the tissue depends on the requested (mechanical) flexibility of the product. Phenolic resins, caoutchouc (natural rubber) or dispersions of synthetics are the common materials for this purpose.

#### **Vulcanised fibre**

Vulcanised fibre is commonly not pretreated.

### 16.2.2.2.2 Coating of the backing with bonding materials

The backings are coated with the bonding material in a coating machine, e.g. by means of a spreader roll (application of the make coat).

Depending on the application profile of the abrasive, there are different bonding materials. In addition to natural products such as hide glue and starch or resins (e.g. epoxy, urea, alkyd and polyurethane resins), phenolic resins are mostly applied. The advantages of phenolic resins compared to other bonding materials are a better adherence, a lower sensitivity against humidity and a higher thermal resistance. Aqueous phenolic resins are often preferred to the slightly more flexible products with a solvent content because of their easier handling process.

The drying and hardening process is carried out in the festoon pre-dryer. The backing material runs in large loops over sticks through the various temperature zones of the dryer or hardener, which is heated with circulating hot air. Thus, a specific dwell time corresponding to the bonding material is guaranteed.

If necessary, the web is stretched at the end of the dryer. For the final imbedding and fixing (size coating), several binding layers may be applied.

The conclusive hardening of phenolic resins is carried out at temperatures up to a range of 100–140 °C, depending on the bonding and the abrasive grain. This procedure takes place in a drying channel (such as in predrying) or after spooling in the hardening oven.

### 16.2.2.2.3 Coating of the backing with grain

#### **Electrostatic grain coating**

The backing runs through an electrostatic field. The side with the make coat is positioned downwards. At the same time, the abrasive grain runs for a certain distance under the coated backing on a conveyor belt. When the abrasive grain enters the electrostatic field, it is charged and thus attracted by the backing above. It reaches the coated backing and trickles into the make

coat. During this process, the grains are oriented with its sharp ends vertical to the backing. As a consequence, the abrasive obtains outstanding cutting characteristics.

#### **Mechanical grain coating**

Before the electrostatic grain coating, the coated abrasives were coated with the so-called 'gravity grain coating'. This procedure is still in use in some special fields. The abrasive grain falls over a hopper and free falls onto the make coat coated backing. Most of the grain clings in the binding layer. The surplus grain falls into a collecting funnel when the direction of the backing web is changed. From there, the abrasive grain can be recycled and used again.

#### **Other coatings**

For special applications where fine grain sizes are needed, the abrasives are coated in a third procedure – the elutriating process. The grain, polish powder or filling material is directly added to the bonding material. In a sizer, the well mixed mass runs over reverse rolls and is applied to the backing material. The application of a make coat is not necessary here.

#### **16.2.2.4 Flexing**

After the spooler, the rolls of abrasive tissue, paper or fibre (jumbos) have to be further treated in order to guarantee the quality of the products depending on its further purpose. To this end, the rigid coating with grain and bonding materials is rendered flexible after hardening and conditioning. Depending on the kind of abrasive used, there are several particular methods for flexing. They can be differentiated between 90°-flexing and cross-flexing. For the 90°-flexing, the non-sprinkled side of the abrasive is drawn over a flexing roll.

The degree of flexing depends on the radius of the flexing roll. The flexing is realised according to the specific purpose and properties of each abrasive. When the layer of the bond material and the abrasive grain is broken due to the very high flexing, this leads to reduced abrasive capacity of the product.

#### **16.2.2.3 Components of installations and required differentiation**

The described processes are typically realised in installations with the components listed in Table 16.6.

**Table 16.6: Components of installation and differentiation**

Unrolling	Unroll stands with a working width of 900–1650 mm and a speed of 10–50 m/min are in use
Printing	Usually two to three printing rolls are used
Roll coating (alternative: spraying)	Realised through a two printing roller with ladle tank or alternatively with jet spraying
Grain coating field (electrostatic or mechanic)	Use of a grain coating field with plate capacitor (around 30 kV or more voltage) or grain coating hopper (hopper gate on the backing)
Dryer (loop dryer or tensionless dryer)	Temperature of 35–110 °C (in the loop dryer, the coated web runs through in loops; in the tensionless dryer, the web is transported flat without contact through the dryer)
Humidification	Usually at the end of the dryer in a vapour zone
Spooling	Realised through a running lap winder
End drying	Use of a small dimensioned dryer, usually with the capacity for single jumbo rolls
Exhaust air treatment	Application of dust separators and thermal or regenerative post-combustion at 700 °C (or higher) with or without energy recovery (depending onsite-specific circumstances and energy or heat demand)
Water treatment	Biological water treatment plant or bioreactor
Flexing	Flex machines consisting of unrolling, flexing rods (the web runs with the back side in a narrow angle over the flexing rod in order to make the product flexible), roll up
Conversion	Gluing of abrasive belts to overlapping endless belts is prepared in machines for cutting into sections before gluing under pressure and heat in pressure units. PU-glues containing solvent may be used. Cutting and punching devices produce sheets, discs and rolls
<b>Source:</b> [12, UBA Germany, 2002 updated FEPA/VDS 2016 ]	

### System differentiations related to explosion protection

It is usually necessary to install explosion protection equipment around the applying units and the open run of webs. The applying units and the open run of webs are equipped with properly working suction units. Monitoring takes place by suitable measures appropriate to the site-specific conditions.

Where required, all electrical equipment is explosion protected according to these guidelines. All loop driving devices are situated outside the loop zone. The loop zone is exclusively indirectly heated.

The maximum speed of the production line is controlled to 50 % of the LEL of the substance with the lowest flashpoint.

In order to achieve a negative pressure and to guarantee the 50 % LEL, the dryer is constantly driven with a determined exhaust air amount.

The waste gas streams are collected and led to the waste gas treatment installation. The air streams are monitored. The grain coating room is equipped with an extraction unit and monitored as well.

The coating machines along with the electrostatic grain coating installations are protected by fire extinguishing systems.

The pre- and the main dryer are completely protected by inner fire extinguishing systems (dry ascending pipes).



### 16.2.3 Current consumption and emission levels in abrasives manufacturing

[As no plants above the IED capacity threshold were identified, no data collection took place. The following sections are the same as in the original STS BREF (2007)]

#### 16.2.3.1 Mass balances

In Table 16.7, Table 16.8 and Table 16.9, mass balances of three existing plants are shown. Table 16.7 shows the mass balance of an abrasive production plant with a typical product mix of different binding types:

- hide glue (solvent-free)
- partial synthetic resin (solvent-free)
- synthetic resin (almost solvent-free).

The balance has been established on real values with specific values related to 10 kilotonnes final product per year. The capacity of this plant corresponds approximately to this amount. The output values are half hour mean values.

**Table 16.7: Mass balance of abrasive manufacturing in plant 1**

Input		Output	
<b>Raw materials</b> <sup>(1)</sup>			
Paper/fabric	4701 t/yr	Product	10000 t/yr
Abrasive grain	3214 t/yr	Waste for combustion	77 t/yr
Bonding material including phenols and other synthetic resins	2436 t/yr	Waste for disposal	37 t/yr
		Hazardous waste	116 t/yr
<b>Solvents</b> <sup>(2)</sup>			
Water	827 t/yr	Water	827 t/yr
Organic solvents <sup>(3)</sup>	275 t/yr	Fugitive emissions of VOC	38 t/yr
		TOC after thermal post-combustion	<20 mg/m <sup>3</sup>
		NO <sub>x</sub> after thermal post-combustion	<100 mg/m <sup>3</sup>
		CO after thermal post-combustion	<100 mg/m <sup>3</sup>
		Relative oxygen of a thermal or regenerative post-combustion	18 – 21 %
<b>Energy (in kWh/yr)</b>			
Electric current	3007243		
Gas	21871076		
Hot water	16379075		
Note: [38, TWG, 2004]			
<sup>(1)</sup> The input of raw material adds up to 10351 t and the output only to 10230 t (mass balance is not closed)			
<sup>(2)</sup> Similarly with the organic solvent (input 1102 t, output 865 t)			
<sup>(3)</sup> Differences in the mass balances are due to the combustion of solvents and other additives in the waste gas treatment systems [78, TWG, 2005][12, UBA Germany, 2002]			

Table 16.8 shows the mass balance of plant 2, where only fabric is assembled by means of preservation. The manufactured fabric is used as backing for coated abrasives. Light and heavy cotton and also heavy polyester fabrics are impregnated. The values shown are exclusively values of the fabric impregnation. The mass balance has been established on real values with specific values related to 10 kilotonnes final product per year. The capacity of this plant is about 5 kilotonnes final product per year. The corresponding abrasive production is carried out in plant 3, which is described in Table 16.9.

Table 16.8: Mass balance of impregnation plant for the manufacturing of abrasives in plant 2

Input		Output	
<b>Raw materials</b> <sup>(1)</sup>			
Raw fabric	8101 t/yr	Impregnated fabric	10000 t/yr
Corresponding to m <sup>2</sup> /yr	24261025	Corresponding to m <sup>2</sup> /yr	24261025
Phenolic resins	1002 t/yr	Hazardous waste	185 t/yr
Lattices	2104 t/yr	Waste for disposal	133 t/yr
Hide glue/starch	585 t/yr	Waste for further treatment	484 t/yr
Additives	670 t/yr	Paper waste	117 t/yr
<b>Solvents</b> <sup>(2)</sup>			
Organic solvents <sup>(3)</sup>	125 t/yr	Fugitive emissions of VOC	12 t/yr
		TOC after thermal post-combustion	<20 mg/m <sup>3</sup>
		NO <sub>x</sub> after thermal post-combustion	<100 mg/m <sup>3</sup>
		CO after thermal post-combustion	<100 mg/m <sup>3</sup>
		Dust	<10 mg/m <sup>3</sup>
		Relative oxygen of a thermal or regenerative post-combustion	18 – 21 %
<b>Accessory agents</b>			
Water (m <sup>3</sup> /yr)	101630	Waste water	
		Manufacturing	46750 m <sup>3</sup> /yr
		Cooling	8794 m <sup>3</sup> /yr
		Vapour	21752 m <sup>3</sup> /yr
		Sanitary	7692 m <sup>3</sup> /yr
		Cleaning	16639 m <sup>3</sup> /yr
<b>Energy (in kWh/yr)</b>			
Energy	46258325		
Note: [38, TWG, 2004]			
<sup>(1)</sup> The input of raw material adds up to 12462 t and the output only to 10919 t (mass balance is not closed)			
<sup>(2)</sup> The same with the organic solvent (input 125 t, output 12 t).			
<sup>(3)</sup> Differences in the mass balances are due to the combustion of solvents and other additives in the waste gas treatment systems [78, TWG, 2005][12, UBA Germany, 2002]			

Table 16.9 shows the mass balance of plant 3, which is a production site for coated abrasives. It comprises several machines, however without pretreatment of the backings. The production includes hand grinding and dry grinding papers, waterproof paper and tissue abrasives, light and medium as well as heavy fabric qualities and abrasive non-woven products. The balance has been established on real values with specific values related to 5000000 m<sup>2</sup>/yr final product. The capacity of this plant is slightly above this amount. Output values are half hour mean values.

Table 16.9: Mass balance of abrasive manufacturing in plant 3

Input <sup>(1)</sup>		Output <sup>(1)</sup>	
<b>Raw material</b>			
Impregnated backing	5000000 m <sup>2</sup> /yr	Product	5000000 m <sup>2</sup> /yr
Abrasive grain	992 t/yr		
<b>Solvents</b>			
Organic solvents <sup>(2)</sup>	259 t/yr	Fugitive emissions of VOC	30.1 t/yr
		TOC after thermal post-combustion	<20 mg/m <sup>3</sup>
		NO <sub>x</sub> after thermal post-combustion	<100 mg/m <sup>3</sup>
		CO after thermal post-combustion	<100 mg/m <sup>3</sup>
		Dust	<10 mg/m <sup>3</sup>
		Relative oxygen of a thermal or regenerative post-combustion	18 – 21 %
Phenolic and other resins	520 t/yr		
Lattices	22.2 t/yr		
Accessory agents			
Water	32063 m <sup>3</sup> /yr		
Energy			
Gas and current	34831581 kWh/yr		
Note: [38, TWG, 2004]			
<sup>(1)</sup> The mass balance is not closed			
<sup>(2)</sup> Differences in the mass balances are due to the combustion of solvents and other additives in the waste gas treatment systems [78, TWG, 2005][12, UBA Germany, 2002]			

### 16.2.3.2 Consumptions

See Section 16.2.3.1 for the consumption of raw materials, solvents, water and energy.

### 16.2.3.3 Emissions

#### 16.2.3.3.1 Emissions to air

#### General background on industries using adhesives

In the IED, the manufacture of abrasives is grouped with other industries using adhesives. Other relevant industries that are:

- addressed in this document: the production of adhesive tapes, abrasives, the transportation sector (passenger cars, commercial vehicles, rail vehicles, and aircraft), and the wood material and furniture industry
- not addressed in this document: composite foils, mobile homes, the manufacture of shoes and leather goods.

Abrasive manufacture cannot be disaggregated from the following data, but it does provide some background. At EU-25 level in 2000 (according to the RAINS model) NMVOC emissions were 257.6 kt representing 2.4% of total NMVOC emissions. Total activity was 680 kt of adhesives used, and the average emission factor is about 378.8 g NMVOC/kg of adhesives meaning that emissions from this sector are already partly treated\* in EU-25 (the untreated\* emission factor being 780 g/kg). EGTEI estimate reductions achievable across all the industries using solvent to be 76 to 98 %; however, it is not known how representative this is of abrasive manufacture. (\*Treated/untreated in this context means not only waste gas treatment but also other measures to reduce VOC emissions).

### Specific data for the manufacture of abrasives

Examples of emissions from three plants in Germany are given in Section 16.2.3.1.

After waste gas treatment, the emission levels achieved are <20 mg organic carbon/m<sup>3</sup>, 100 mg CO/m<sup>3</sup> and 100 mg NO<sub>x</sub>/m<sup>3</sup>. The maximum limits for phenol and formaldehyde (20 mg/m<sup>3</sup>) are also kept.

#### 16.2.3.3.2 Emissions to water

Waste water arises from the cleaning of machine parts, mainly containing phenol and fluoride. The following waste water treatments are normally carried out before discharge to a municipal waste water treatment plant:

- neutralisation
- fluoride precipitation
- filtration
- biological treatment.

The techniques mentioned above are described in detail in the STM BREF [59, EIPPCB, 2006] and in the CWW BREF [67, EIPPCB, 2003].

The following emission levels or lower are achieved:

- total phenol 75 mg/l
- volatile in steam phenol 20 mg/l
- fluoride 40 mg/l
- sulphate 200 mg/l
- iron 1 mg/l
- aluminium 1 mg/l
- zinc 1 mg/l.

#### 16.2.3.3.3 Waste

According to the product spectrum, waste arises during conversion in the form of cuttings (e.g. edges, punchings). In some cases, a proportion of these cuttings may be separated, recut and sold.

### 16.2.4 Techniques to consider in the determination of BAT for the manufacturing of abrasives

[As no plants above the IED capacity threshold were identified, no data collection took place. The following sections are (in principle) the same as in the original STS BREF (2007)]

In Chapter 17, techniques are discussed which might also be applicable to the manufacturing of abrasives. In Table 16.10, the general techniques relevant for the manufacturing of abrasives are shown. These techniques are normally not repeated in this section, unless information specific for this industry was made available. A description of the type of information considered for each technique is given in Table 17.1.

Table 16.10: Reference to techniques generally applicable to the sector

Technique	Section number
Environmental management techniques	17.1
Storage and handling of solvents	17.2
Monitoring	17.3
Water management	17.4
Energy management	17.5
Coating processes and equipment	17.7
Drying	17.8
Cleaning	17.9
Raw material management (including substitution)	17.6
Waste gas treatment	17.10
Waste water treatment	17.11
Waste minimisation and treatment of wastes containing solvent	17.12
Odour abatement	17.13

The EGTEI synopsis sheet for the industrial application of adhesives (see Annex 21.3.1) gives some data on the cost-benefit at a European level of some techniques to reduce VOC emissions. However, the EGTEI approach necessarily has to limit its complexity, and only key techniques are given without consideration of the other BAT factors, such as cross-media effects or of the technical characteristics of individual installations and products [83, EGTEI, 2005].

~~[Conventional solvent-based bonding materials]—~~

~~Proposed for deletion – not a BATC~~

~~**Description:** Solvent based bonding materials are applied where workpieces and application methods require water cooling, e.g. for wet grinding of steel, glass, ceramic, natural or artificial stone and plastics. The required waterproof qualities of the abrasive paper can only be achieved by using solvent based bonding materials.~~

~~Phenolic resin is the most commonly used resin. Others are epoxy resins, polyurethane and urea resins. No information has been made available on the organic solvent content.~~

~~**Achieved environmental benefits:** No data submitted.~~

~~**Cross-media effects:** No data submitted.~~

~~**Operational data:** It is common practice to treat the waste gases containing solvent.~~

~~**Applicability:** This technique is commonly applied. Solvent based bonding materials are necessary for the production of wet grinding abrasives.~~

~~**Economics:** No data submitted.~~

~~**Driving forces for implementation:** No data submitted.~~

~~**Example plants:** No data submitted.~~

~~**Reference literature:** [12, UBA Germany, 2002] [38, TWG, 2004]~~

## 16.2.4.1 Substitution of conventional solvent-based bonding materials

### 16.2.4.1.1 Solvent-free bonding materials

#### Description

Solvent-free bonding materials are hide glue and starch, and partial synthetic resins. In the case of fabrics, they can be recognised for specific product qualities. However, resins are usually applied, because they have a better adherence, a lower sensitivity against humidity and a higher thermal resistance. Water-based phenolic resins are often preferred to the slightly more flexible products with solvent content, because of their easier handling process.

The waterproof qualities required for abrasive paper can only be achieved by using solvent-based bonding materials.

#### Achieved environmental benefits

Solvent emissions are omitted.

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

Solvent-based bonding materials are necessary for the production of wet grinding abrasives. They are commonly applied for the production of dry grinding papers.

#### Economics

No data submitted.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

[12, UBA Germany, 2002] [38, TWG, 2004]

## 16.2.4.2 Drying

### 16.2.4.2.1 Convection drying

*Proposed for deletion*

For a general description, see Section. Loop or tensionless dryers are commonly applied at a temperature of 35–110 °C. In the loop dryer, the coated web runs through in loops. In the tensionless dryer, the web is transported flat and without contact through the dryer.

[12, UBA Germany, 2002]

#### Electromagnetic drying

**Proposed for deletion – not applied in the abrasive industry**

~~For a general description, see Section **Error! Reference source not found.** Electromagnetic drying, i.e. high frequency drying (HF), is commonly applied to water based coatings.~~

~~[12, UBA Germany, 2002]~~

### 16.2.4.3 Waste gas treatment

#### 16.2.4.3.1 Increase of the internal solvent concentration

For a general description, see Section 17.10.3.1. This is commonly applied to increase the solvent reduction efficiency of the waste gas treatment system. The maximum speed of the production line is at 50 % LEL of the substance with the lowest flashpoint. To this end, the speed is electronically blocked. In order to achieve negative pressure and to guarantee the 50 % LEL, the dryer is constantly driven with a determined amount of exhaust air.  
[12, UBA Germany, 2002]

#### 16.2.4.3.2 Containment and collection of waste gases

For a general description, see Section 17.10.2. The waste gas from the places where the web runs open, the units applying bonding material and the dryer are collected and routed to the waste gas treatment system. Fugitive solvent emissions are reduced to a range of 9.6–13.8 % of the total solvent input.  
[12, UBA Germany, 2002] [78, TWG, 2005]

#### 16.2.4.3.3 Dry filter systems

For a general description, see Section 17.10.4.5. Several types of bag filters are applied. The emission values obtained depend on the dust characteristics, filter construction and the filter itself. A static dust concentration of  $< 10 \text{ mg/m}^3$  is achievable. However, typically this is  $20 \text{ mg/m}^3$ .  
[12, UBA Germany, 2002]

#### 16.2.4.3.4 Thermal oxidation

For a general description, see Section 17.10.5.2. At exhaust air volumes of up to  $66\,000 \text{ Nm}^3/\text{h}$ , the installations achieve emission values of  $< 20 \text{ mg VOC/m}^3$  (the half hour mean value).  
[12, UBA Germany, 2002]

#### 16.2.4.3.5 Regenerative thermal oxidation

For a general description, see Sections 17.10.5.4 and 17.10.5.5. This is commonly applied to treat waste gases from the dryers, the places where the web runs open and to the units applying bonding material.

During production, the regenerative oxidiser can work normally autothermal (above  $2\text{--}3 \text{ g/m}^3$  organic solvent in the waste gas). At exhaust air volumes of up to  $66\,000 \text{ Nm}^3/\text{h}$ , the installations achieve emission values of  $< 20 \text{ mg C/m}^3$ ,  $< 100 \text{ mg CO/m}^3$  and  $100 \text{ mg NO}_x/\text{m}^3$  (the half hour mean values). Levels for phenol and formaldehyde of  $< 20 \text{ mg/m}^3$  are achieved.  
[12, UBA Germany, 2002]

#### 16.2.4.3.6 Biological treatment

Is not applicable due to the specific conditions in the abrasive industry. Pilot installations have been tested, however, due to the high and in addition changing concentrations of total C in the raw gas this technology is not applicable in the abrasive industry from a technical as well as from an economic point of view.

The thermal oxidation and the regenerative thermal oxidation are currently seen as BAT in the manufacture of coated abrasives.

~~For a general description, see Section 17.10.7. This technique is sometimes applied to the waste gas from the drying ovens.~~

~~[12, UBA Germany, 2002]~~

WORKING DRAFT IN PROGRESS



## **17 TECHNIQUES TO CONSIDER IN THE DETERMINATION OF BAT APPLICABLE IN ALL STS INDUSTRIES**

This chapter sets out techniques considered generally to have potential for achieving a high level of environmental protection in the industries within the scope of this document. Techniques to be considered for each specific industry can be found in Section X.4 (where X is the specific industry chapter).

Management systems, process-integrated techniques and end-of-pipe measures are included, but a certain amount of overlap exists between these three when seeking the optimum results.

Prevention, control, minimisation and re-cycling procedures are considered as well as the reuse of materials and energy.

Techniques may be presented singly or as combinations (from both this chapter and the relevant Sections X.4) to achieve the objectives of IPPC. Annex IV to the Directive lists a number of general considerations to be taken into account when determining BAT and techniques within this chapter will address one or more of these considerations. As far as possible a standard structure is used to outline each technique, to enable comparison of techniques and an objective assessment against the definition of BAT given in the Directive.

The content of the sections in this chapter and in the Sections X.4 are not an exhaustive list of techniques and others may exist or be developed which may be equally valid within the framework of BAT.

Table 17.1: Information breakdown for each technique described in Chapter 17 and in all the Sections 4 in each of the Chapters 2 to 16

Heading within the section	Type of information included
Description	A brief description of the technique with a view to being used in the BAT conclusions.
Technical description	A more detailed and yet concise technical description using, as appropriate, chemical or other equations, pictures, diagrams and flow charts.
Achieved environmental benefits	The <b>main</b> potential environmental benefits to be gained through implementing the technique (including reduced consumption of energy; reduced emissions to water, air and land; raw material savings; as well as production yield increases, reduced waste, etc.).
Environmental performance and operational data	<p>Actual and <b>plant-specific</b> performance data (including emission levels, consumption levels – of raw materials, water, energy – and amounts of residues/wastes generated) from well-performing installations/plants (with respect to the environment taken as a whole) applying the technique accompanied by the relevant contextual information.</p> <p>Any other useful information on the following items:</p> <ul style="list-style-type: none"> <li>• how to design, operate, maintain, control and decommission the technique;</li> <li>• emission monitoring issues related to the use of the technique;</li> <li>• sensitivity and durability of the technique;</li> <li>• issues regarding accident prevention.</li> </ul> <p>Links between inputs (e.g. nature and quantity of raw material and fuel, energy, water) and outputs (emissions, residues/wastes, products) are highlighted, in particular where relevant to enhancing an understanding of different environmental impacts and their interaction, for example where trade-offs have been made between different outputs such that certain environmental performance levels cannot be achieved at the same time.</p> <p>Emission and consumption data are qualified as far as possible with details of relevant operating conditions (e.g. percentage of full capacity, fuel composition, bypassing of the (abatement) technique, inclusion or exclusion of other than normal operating conditions, reference conditions), sampling and analytical methods, and statistical presentation (e.g. short- and long-term averages, maxima, ranges and distributions).</p> <p>Information on conditions/circumstances hampering the use of the (abatement) technique at full capacity and/or necessitating full or partial bypassing of the (abatement) technique and measures taken to restore full (abatement) capacity.</p>
Cross-media effects	<p>Relevant negative effects on the environment due to implementing the technique, allowing comparison between techniques in order to assess the impact on the environment as a whole. This may include issues such as:</p> <ul style="list-style-type: none"> <li>• consumption and nature of raw materials and water;</li> <li>• energy consumption and contribution to climate change;</li> <li>• stratospheric ozone depletion potential;</li> </ul>

	<ul style="list-style-type: none"> <li>• photochemical ozone creation potential;</li> <li>• acidification resulting from emissions to air;</li> <li>• presence of particulate matter in ambient air (including microparticles and metals);</li> <li>• eutrophication of land and waters resulting from emissions to air or water;</li> <li>• oxygen depletion potential in water;</li> <li>• persistent/toxic/bioaccumulable components (including metals);</li> <li>• generation of residues/waste;</li> <li>• limitation of the ability to reuse or recycle residues/waste;</li> <li>• generation of noise and/or odour;</li> <li>• increased risk of accidents.</li> </ul> <p>The Reference Document on Economics and Cross-media Effects (ECM) should be taken into account.</p>
<p>Technical considerations relevant to applicability</p>	<p>It is indicated whether the technique can be applied throughout the sector. Otherwise, the main general technical restrictions on the use of the technique within the sector are indicated. These may be:</p> <ul style="list-style-type: none"> <li>• an indication of the type of plants or processes within the sector to which the technique cannot be applied;</li> <li>• constraints to implementation in certain generic cases, considering, e.g.: <ul style="list-style-type: none"> <li>○ whether it concerns a new or an existing plant, taking into account factors involved in retrofitting (e.g. space availability) and interactions with techniques already installed,</li> <li>○ plant size, capacity or load factor,</li> <li>○ quantity, type or quality of product manufactured,</li> <li>○ type of fuel or raw material used,</li> <li>○ animal welfare,</li> <li>○ climatic conditions.</li> </ul> </li> </ul> <p>These restrictions are indicated together with the reasons for them.</p> <p>These restrictions are not meant to be a list of the possible local conditions that could affect the applicability of the technique for an individual plant.</p>
<p>Economics</p>	<p>Information on the costs (capital/investment, operating and maintenance including details on how these costs have been calculated/estimated) and any possible savings (e.g. reduced raw material or energy consumption, waste charges, reduced payback time compared to other techniques), or revenues or other benefits including details on how these have been calculated/estimated.</p> <p>Cost data are preferably given in euro (EUR). If a conversion is made from another currency, the data in the original currency and the year when the data were collected is indicated. The price/cost of the equipment or service is accompanied by the year it was purchased.</p>

	<p>Information on the market for the sector in order to put costs of techniques into context.</p> <p>Information relevant to both newly built, retrofitted and existing plants. This should allow assessment, where possible, of the economic viability of the technique for the sector concerned.</p> <p>Information on the cost-effectiveness of the technique (e.g. in EUR per mass of pollutant abated) and related assumptions for their calculation can be reported.</p> <p>The Reference Document on Economics and Cross-media Effects (ECM) and the Reference Report on Monitoring of Emissions to Air and Water from IED Installations (ROM) are taken into account with regard to economic aspects and monitoring costs, respectively.</p>
Driving force for implementation	<p>Where applicable, specific local conditions, requirements (e.g. legislation, safety measures) or non-environmental triggers (e.g. increased yield, improved product quality, economic incentives – e.g. subsidies, tax breaks) which have driven or stimulated the implementation of the technique to date.</p> <p>This subsection should be very short using bullet point lists.</p>
Example plants	<p>Reference to a plant(s) where the technique has been implemented and from which information has been collected and used in writing the section. An indication of the degree to which the technique is in use in the EU or worldwide.</p>
Reference literature	<p>Literature or other reference material (e.g. books, reports, studies) that was used in writing the section and that contains more detailed information on the technique. When the reference material consists of a large number of pages, reference will be made to the relevant page(s) or section(s).</p>

## 17.1 Environmental management techniques

### 17.1.1 Environmental management tools

#### Description

The best environmental performance is usually achieved by the installation of the best technology and its operation in the most effective and efficient manner. This is recognised by the IPPC Directive definition of ‘techniques’ as *‘both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned’*.

For IPPC installations an Environmental Management System (EMS) is a tool that operators can use to address these design, construction, maintenance, operation and decommissioning issues in a systematic, demonstrable way. An EMS includes the organisational structure, responsibilities, practices, procedures, processes and resources for developing, implementing, maintaining, reviewing and monitoring the environmental policy. Environmental Management Systems are most effective and efficient where they form an inherent part of the overall management and operation of an installation.

Within the European Union, many organisations have decided on a voluntary basis to implement environmental management systems based on EN ISO 14001:1996 or the EU Eco-management and audit scheme EMAS. EMAS includes the management system requirements of EN ISO 14001, but places additional emphasis on legal compliance, environmental performance and employee involvement; it also requires external verification of the management system and validation of a public environmental statement (in EN ISO 14001 self-declaration is an alternative to external verification). There are also many organisations that have decided to put in place non-standardised EMSs.

While both standardised systems (EN ISO 14001:1996 and EMAS) and non-standardised (‘customised’) systems in principle take the *organisation* as the entity, this document takes a more narrow approach, not including all activities of the organisation e.g. with regard to their products and services, due to the fact that the regulated entity under the IPPC Directive is the *installation* (as defined in Article 2).

An environmental management system (EMS) for an IPPC installation can contain the following components:

- (a) definition of an environmental policy;
- (b) planning and establishing objectives and targets;
- (c) implementation and operation of procedures;
- (d) checking and corrective action;
- (e) management review;
- (f) preparation of a regular environmental statement;
- (g) validation by certification body or external EMS verifier;
- (h) design considerations for end-of-life plant decommissioning;
- (i) development of cleaner technologies;
- (j) benchmarking.

These features are explained in somewhat greater detail below. For detailed information on components (a) to (g), which are all included in EMAS, the reader is referred to the reference literature indicated below.

**(a) Definition of an environmental policy**

Top management are responsible for defining an environmental policy for an installation and ensuring that it:

- is appropriate to the nature, scale and environmental impacts of the activities;
- includes a commitment to pollution prevention and control;
- includes a commitment to comply with all relevant applicable environmental legislation and regulations, and with other requirements to which the organisation subscribes;
- provides the framework for setting and reviewing environmental objectives and targets;
- is documented and communicated to all employees;
- is available to the public and all interested parties.

**(b) Planning, i.e.**

- procedures to identify the environmental aspects of the installation, in order to determine those activities which have or can have significant impacts on the environment, and to keep this information up-to-date;
- procedures to identify and have access to legal and other requirements to which the organisation subscribes and that are applicable to the environmental aspects of its activities;
- establishing and reviewing documented environmental objectives and targets, taking into consideration the legal and other requirements and the views of interested parties;
- establishing and regularly updating an environmental management programme, including designation of responsibility for achieving objectives and targets at each relevant function and level as well as the means and timeframe by which they are to be achieved.

**(c) Implementation and operation of procedures**

It is important to have systems in place to ensure that procedures are known, understood and complied with, therefore effective environmental management includes:

**(i) Structure and responsibility**

- defining, documenting and communicating roles, responsibilities and authorities, which includes appointing one specific management representative;
- providing resources essential to the implementation and control of the environmental management system, including human resources and specialised skills, technology and financial resources.

**(ii) Training, awareness and competence**

- identifying training needs to ensure that all personnel whose work may significantly affect the environmental impacts of the activity have received appropriate training.

**(iii) Communication**

- establishing and maintaining procedures for internal communication between the various levels and functions of the installation, as well as procedures that foster a dialogue with external interested parties and procedures for receiving, documenting and, where reasonable, responding to relevant communication from external interested parties.

**(iv) Employee involvement**

- involving employees in the process aimed at achieving a high level of environmental performance by applying appropriate forms of participation such as the suggestion-book system or project-based group works or environmental committees.

## (v) Documentation

- establishing and maintaining up-to-date information, in paper or electronic form, to describe the core elements of the management system and their interaction and to provide direction to related documentation.

## (vi) Efficient process control

- adequate control of processes under all modes of operation, i.e. preparation, start-up, routine operation, shutdown and abnormal conditions;
- identifying the key performance indicators and methods for measuring and controlling these parameters (e.g. flow, pressure, temperature, composition and quantity);
- documenting and analysing abnormal operating conditions to identify the root causes and then addressing these to ensure that events do not recur (this can be facilitated by a 'no-blame' culture where the identification of causes is more important than apportioning blame to individuals).

## (vii) Maintenance programme

- establishing a structured programme for maintenance based on technical descriptions of the equipment, norms etc. as well as any equipment failures and consequences;
- supporting the maintenance programme by appropriate record keeping systems and diagnostic testing;
- clearly allocating responsibility for the planning and execution of maintenance.

## (viii) Emergency preparedness and response

- establishing and maintaining procedures to identify the potential for and response to accidents and emergency situations, and for preventing and mitigating the environmental impacts that may be associated with them.

**(d) Checking and corrective action, i.e.**

## (i) Monitoring and measurement

- establishing and maintaining documented procedures to monitor and measure, on a regular basis, the key characteristics of operations and activities that can have a significant impact on the environment, including the recording of information for tracking performance, relevant operational controls and conformance with the installation's environmental objectives and targets (see also the Reference document on Monitoring of Emissions);
- establishing and maintaining a documented procedure for periodically evaluating compliance with relevant environmental legislation and regulations.

## (ii) Corrective and preventive action

- establishing and maintaining procedures for defining responsibility and authority for handling and investigating non-conformance with permit conditions, other legal requirements as well as objectives and targets, taking action to mitigate any impacts caused and for initiating and completing corrective and preventive action that are appropriate to the magnitude of the problem and commensurate with the environmental impact encountered.

## (iii) Records

- establishing and maintaining procedures for the identification, maintenance and disposition of legible, identifiable and traceable environmental records, including training records and the results of audits and reviews.

## (iv) Audit

- establishing and maintaining (a) programme(s) and procedures for periodic environmental management system audits that include discussions with personnel, inspection of operating conditions and equipment and reviewing of records and documentation and that results in a written report, to be carried out impartially and objectively by employees (internal audits) or external parties (external audits), covering the audit scope, frequency and methodologies, as well as the responsibilities and requirements for conducting audits and reporting results, in order to determine whether or not the environmental management system conforms to planned arrangements and has been properly implemented and maintained;
- completing the audit or audit cycle, as appropriate, at intervals of no longer than three years, depending on the nature, scale and complexity of the activities, the significance of associated environmental impacts, the importance and urgency of the problems detected by previous audits and the history of environmental problems – more complex activities with a more significant environmental impact are audited more frequently
- having appropriate mechanisms in place to ensure that the audit results are followed up.

(v) Periodic evaluation of legal compliance

- reviewing compliance with the applicable environmental legislation and the conditions of the environmental permit(s) held by the installation;
- documentation of the evaluation.

(e) **Management review, i.e.**

- reviewing, by top management, at intervals that it determines, the environmental management system, to ensure its continuing suitability, adequacy and effectiveness;
- ensuring that the necessary information is collected to allow management to carry out this evaluation;
- documentation of the review.

(f) **Preparation of a regular environmental statement**

- preparing an environmental statement that pays particular attention to the results achieved by the installation against its environmental objectives and targets. It is regularly produced – from once a year to less frequently depending on the significance of emissions, waste generation etc. It considers the information needs of relevant interested parties and it is publicly available (e.g. in electronic publications, libraries etc.).

When producing a statement, the operator may use relevant existing environmental performance indicators, making sure that the indicators chosen:

- i. give an accurate appraisal of the installation's performance;
- ii. are understandable and unambiguous;
- iii. allow for year on year comparison to assess the development of the environmental performance of the installation;
- iv. allow for comparison with sector, national or regional benchmarks as appropriate;
- v. allow for comparison with regulatory requirements as appropriate.

(g) **Validation by certification body or external EMS verifier**

- having the management system, audit procedure and environmental statement examined and validated by an accredited certification body or an external EMS verifier can, if carried out properly, enhance the credibility of the system.



**(h) Design considerations for end-of-life plant decommissioning**

- giving consideration to the environmental impact from the eventual decommissioning of the unit at the stage of designing a new plant, as forethought makes decommissioning easier, cleaner and cheaper;
- decommissioning poses environmental risks for the contamination of land (and groundwater) and generates large quantities of solid waste. Preventive techniques are process-specific but general considerations may include:
  - i. avoiding underground structures;
  - ii. incorporating features that facilitate dismantling;
  - iii. choosing surface finishes that are easily decontaminated;
  - iv. using an equipment configuration that minimises trapped chemicals and facilitates drain-down or cleaning;
  - v. designing flexible, self-contained units that enable phased closure;
  - vi. using biodegradable and recyclable materials where possible.

**(i) Development of cleaner technologies**

- environmental protection should be an inherent feature of any process design activities carried out by the operator, since techniques incorporated at the earliest possible design stage are both more effective and cheaper. Giving consideration to the development of cleaner technologies can for instance occur through R&D activities or studies. As an alternative to internal activities, arrangements can be made to keep abreast with – and where appropriate – commission work by other operators or research institutes active in the relevant field.

**(j) Benchmarking, i.e.**

- carrying out systematic and regular comparisons with sector, national or regional benchmarks, including for energy efficiency and energy conservation activities, choice of input materials, emissions to air and discharges to water (using for example the European Pollutant Emission Register, EPER), consumption of water and generation of waste.

**Standardised and non-standardised EMSs**

An EMS can take the form of a standardised or non-standardised ('customised') system. Implementation and adherence to an internationally accepted standardised system such as EN ISO 14001:1996 can give higher credibility to the EMS, especially when subject to a properly performed external verification. EMAS provides additional credibility due to the interaction with the public through the environmental statement and the mechanism to ensure compliance with the applicable environmental legislation. However, non-standardised systems can in principle be equally effective provided that they are properly designed and implemented.

(Regulation (EC) No 761/2001 of the European parliament and of the council allowing voluntary participation by organisations in a Community eco-management and audit scheme (EMAS), OJ L 114, 24/4/2001, [http://europa.eu.int/comm/environment/emas/index\\_en.htm](http://europa.eu.int/comm/environment/emas/index_en.htm))

(EN ISO 14001:2004, <http://www.iso.ch/iso/en/iso9000-14000/iso14000/iso14000index.html>;  
<http://www.tc207.org>)

**Achieved environmental benefits**

Implementation of and adherence to an EMS focuses the attention of the operator on the environmental performance of the installation. In particular, the maintenance of and compliance with clear operating procedures for both normal and abnormal situations and the associated lines

of responsibility should ensure that the installation's permit conditions and other environmental targets and objectives are met at all times.

Environmental management systems typically ensure the continuous improvement of the environmental performance of the installation. The poorer the starting point is, the more significant short-term improvements can be expected. If the installation already has a good overall environmental performance, the system helps the operator to maintain the high performance level.

### **Cross-media effects**

Environmental management techniques are designed to address the overall environmental impact, which is consistent with the integrated approach of the IPPC Directive.

### **Operational data**

No specific information reported.

### **Applicability**

The components described above can typically be applied to all IPPC installations. The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

### **Economics**

It is difficult to accurately determine the costs and economic benefits of introducing and maintaining a good EMS. A number of studies are presented below. However, these are just examples and their results are not entirely coherent. They might not be representative for all sectors across the EU and should thus be treated with caution.

A Swedish study carried out in 1999 surveyed all 360 ISO-certified and EMAS-registered companies in Sweden. With a response rate of 50 %, it concluded among other things that:

- the expenses for introducing and operating EMS are high but not unreasonably so, save in the case of very small companies. Expenses are expected to decrease in the future;
- a higher degree of co-ordination and integration of EMS with other management systems is seen as a possible way to decrease costs;
- half of all the environmental objectives and targets give payback within one year through cost savings and/or increased revenue;
- the largest cost savings were made through decreased expenditure on energy, waste treatment and raw materials;
- most of the companies think that their position on the market has been strengthened through the EMS. One-third of the companies report increasing revenue due to EMS.

In some Member States reduced supervision fees are charged if the installation has a certification.

A number of studies show that there is an inverse relationship between company size and the cost of implementing an EMS. A similar inverse relationship exists for the payback period of invested capital. Both elements imply a less favourable cost-benefit relationship for implementing an EMS in SMEs compared to larger companies.

According to a Swiss study, the average cost for building and operating ISO 14001 can vary:

- for a company with between 1 and 49 employees: CHF 64 000 (EUR 44 000) for building the EMS and CHF 16 000 (EUR 11 000) per year for operating it

- for an industrial site with more than 250 employees: CHF 367000 (EUR 252 000) for building the EMS and CHF 155 000 (EUR 106 000) per year for operating it.

These average figures do not necessarily represent the actual cost for a given industrial site because this cost is also highly dependent on the number of significant items (pollutants, energy consumption,...) and on the complexity of the problems to be studied.

A recent German study (Schaltegger, Stefan and Wagner, Marcus, *Umweltmanagement in deutschen Unternehmen - der aktuelle Stand der Praxis*, February 2002, p. 106) shows the following costs for EMAS for different branches. It can be noted that these figures are much lower than those of the Swiss study quoted above. This is a confirmation of the difficulty to determine the costs of an EMS.

Costs for building (EUR):

– minimum	18750
– maximum	75000
– average	50000

Costs for validation (EUR):

– minimum	5000
– maximum	12500
– average	6000

A study by the German Institute of Entrepreneurs (Unternehmerinstitut/Arbeitsgemeinschaft Selbständiger Unternehmer UNI/ASU, 1997, *Umweltmanagementbefragung - Öko-Audit in der mittelständischen Praxis - Evaluierung und Ansätze für eine Effizienzsteigerung von Umweltmanagementsystemen in der Praxis*, Bonn.) gives information about the average savings achieved for EMAS per year and the average payback time. For example, for implementation costs of EUR 80000 they found average savings of EUR 50000 per year, corresponding to a payback time of about one and a half years.

External costs relating to verification of the system can be estimated from guidance issued by the International Accreditation Forum (<http://www.iaf.nu>).

### **Driving force for implementation**

Environmental management systems can provide a number of advantages, for example:

- improved insight into the environmental aspects of the company;
- improved basis for decision-making;
- improved motivation of personnel;
- additional opportunities for operational cost reduction and product quality improvement;
- improved environmental performance;
- improved company image;
- reduced liability, insurance and non-compliance costs;
- increased attractiveness for employees, customers and investors;
- increased trust of regulators, which could lead to reduced regulatory oversight;
- improved relationship with environmental groups.

### **Example plants**

The features described under (a) to (e) above are elements of EN ISO 14001:1996 (now EN ISO 14001: 2004) and the European Community Eco-Management and Audit Scheme (EMAS), whereas the features (f) and (g) are specific to EMAS. These two standardised systems are applied in a number of IPPC installations. As an example, 357 organisations within the EU chemical and chemical products industry (NACE code 24) were EMAS registered in July 2002, most of which operate IPPC installations.

In the UK, the Environment Agency of England and Wales carried out a survey among IPC (the precursor to IPPC) regulated installations in 2001. It showed that 32 % of respondents were certified to ISO 14001 (corresponding to 21 % of all IPC installations) and 7 % were EMAS registered. All cement works in the UK (around 20) are certified to ISO 14001 and the majority are EMAS registered. In Ireland, where the establishment of an EMS (not necessarily of a standardised nature) is required in IPC licenses, an estimated 100 out of approximately 500 licensed installations have established an EMS according to ISO 14001: 2004, with the other 400 installations having opted for a non-standardised EMS.

In the Netherlands, specific EMS exist for SMEs to reduce the cost and management time required for the introduction of systems.

### Reference literature

- Regulation (EC) No 761/2001 of the European parliament and of the council allowing voluntary participation by organisations in a Community eco-management and audit scheme (EMAS), OJ L 114, 24/4/2001, [http://europa.eu.int/comm/environment/emas/index\\_en.htm](http://europa.eu.int/comm/environment/emas/index_en.htm)
- EN ISO 14001:2004:
  - <http://www.iso.ch/iso/en/iso9000-14000/iso14000/iso14000index.html>;
  - <http://www.tc207.org> [78, TWG, 2005]

## 17.1.2 Ongoing environmental improvement and cross-media issues

### Description

An important component of an EMS is maintaining overall environmental improvement. It is essential that the operator understands what happens to the inputs (understanding the process), e.g. solvents, and how their consumption leads to emissions. It is equally important that when controlling significant inputs and outputs to maintain the correct balance between solvent emissions reduction and cross-media effects, such as energy, water and raw materials consumption. This reduces the environmental footprint of the installation.

Whilst the solvents balance (see Section 17.3.1) is important in these industries, all significant consumption and emissions should be managed in a co-ordinated manner for the short, medium and long term, in conjunction with financial planning and investment cycles, i.e. adapting short-term end-of-pipe solutions to solvents emissions may tie the operator to long term higher energy consumption, and postpone investment in more environmentally beneficial solutions. This will require some consideration of the cross-media issues, and assistance with these and the costing and cost-benefits issues is given in the ECM REF [50, COM, 2005] and in Section 17.1.5.

### Achieved environmental benefits

Long-term reduction in solvents emissions, with reduced water and energy consumption.

### Cross-media effects

A part of the operation's consumption or emissions, such as solvents emissions, may be higher proportionately for a period until longer term investment is made.

### Operational data

No data submitted.

### Applicability

The extent of this exercise will depend on the installation size, and the number of the variables. A full cross-media study is carried out infrequently. See Example plants, below.

### Economics

Enabling capital investment to be made in an informed manner for reduction of the overall environmental benefit and best value for money.

### Driving force for implementation

No data submitted.

### Example plants

An example of considering the cross-media effects is given in the ECM REF [50, COM, 2005].

Applicability to SMEs: Bovince Ltd, London, UK, are a small printing company with about 48 employees, specialising in screen and digital printing. They have a sustainability policy, and operate an EMS with a continuous improvement programme. The progressive introduction of automatic screen cleaning with solvent recovery, ultraviolet inks for as many jobs as possible and good housekeeping has led to a 50 % reduction in solvent consumption since 1996, with cost savings of about EUR 90 000 between 1996 and 2000.

Two theoretical examples are:

1. In a paint shop painting metal components, the need to reduce fugitive solvent emissions is identified as a result of a solvent balance. Key options include the installation of additional extraction equipment and larger end-of-pipe thermal oxidation, or the change to a low solvent process for part of the coating. The former can be installed more quickly, but will significantly increase energy for extraction fans, and support fuel for the thermal oxidation. There will be no reduction in solvent usage, so the management of fugitive emissions from handling, cleaning, etc. remains. A low solvent paint process can be installed, using less energy and 50 % less solvents, but more water. It may cost more in capital, downtime and operator training/familiarisation, however operating costs may be lower. The balance of capital and operating costs is a normal good practice business decision. Data on energy and water consumption, solvent emission and other emissions may be gained from suppliers, other operators possibly, trade associations, and/or guidance data published internationally and nationally, such as environmental costing models, which may also evaluate cost-benefit (see Section 17.1.5).
2. A vehicle manufacturer is seeking to reduce solvent emissions further. A large step change can be achieved, but this requires replacement of the entire paint shop, which has an operating life of 25 years and a capital cost of about EUR 500000. The energy consumption of the paint shop is about 38–52 % of the entire power consumption of the plant and in the order of 160 000–240 000 MWh (of which 60 % is gas). The amount of raw material used, the application efficiency and the amount of solvents lost may also be affected by the degree of automation. The selection of which type of paint and application system, the amount of automation the amount of waste gas treatment and paint system requires a consideration of the operating and capital costs, as well as the consumption and emissions, over the payback period of the investment. The operating life of the existing paint shop must also be taken into account.

### Reference literature

[38, TWG, 2004] [50, COM, 2005] [106, ACEA, 2005] [78, TWG, 2005] [109, COM, 2006]

## 17.1.3 Overall environmental performance

### Description

Identification of the process areas / sections / steps that have the greatest contribution to emissions and consumption and derive improvement actions.

### Technical description

- Identify the process areas/ sections/ steps that have the greatest contribution to the emissions and consumption and the greatest potential for improvement.
- identify corrective / improvement actions to minimise emissions and consumption..
- regular (e.g. on a monthly or annual basis) update of the collected data.

- disseminate the best practices within the installation/group and/or industry sector.

**Achieved environmental benefits**

Reduction of consumption of materials, energy and water. Reduction of emissions, principally of VOCs.

**Environmental performance and operational information**

Incremental improvements that maintain and improve the environmental performance of the installation.

**Cross-media effects**

None.

**Technical considerations relevant to applicability**

**Economics**

The staff time required.

**Driving force for implementation**

Potential cost savings in materials and production efficiency.

**Example plants**

Renault Douai, FR

**Reference literature**

[181, COM, 2017]

### **17.1.4 Benchmarking consumption and emissions and subsequent action**

**Description**

Benchmarking is the systematic recording of inputs (raw materials, water and energy) and outputs (emissions to air and water, and as waste), and the regular comparisons of these with previous data for the installation, with its sector, national or regional benchmarks (see Section 17.1.1 (j)). When data are benchmarked in an installation, it is good practice to maintain a system to identify any actions required from the data gathered and bring these actions to a conclusion (see Section 20.1.1(d)), including:

- identifying a person or persons responsible for evaluating and taking action on the data;
- informing those responsible for plant performance, including alerting operators rapidly and effectively to variations from normal performance;
- other investigations to ascertain why performance has varied or is out of line with external benchmarks.

**Achieved environmental benefits**

Assists individual installations to assess their environmental performance with other installations. Assists in identifying techniques used by the best performing installations. Can identify or assist in identifying unplanned or unobserved events, such as pipe or pump seal leakage, losses to soil and groundwater, etc.

**Cross-media effects**

No data submitted.

**Operational data**

Provides benchmarks and assessments of operational environmental performance of installations and techniques. Data can be gathered and compared on different levels such as:

technique or activity (press, process tank, or process line), site, sector, regional or national. It can be made public while keeping individual site identities confidential. For example:

- solvents consumed and emitted. Fugitive emissions, and therefore total emissions, can only be determined using a solvent balance, Section 17.3.1. Appropriate issues for benchmarking can be identified when carrying out a solvent balance (see Annexes 0 and 21.4);
- water consumption – this is important when water-based coatings are used;
- energy consumption, e.g. from drying and abatement equipment;
- raw materials consumption, e.g. inks, wipes, paper, in press set-up, up to 10 % of the substrate can be wasted;
- wastes generated;
- significant pollutants emitted to water, air or soil/groundwater.

### **Applicability**

Appropriate benchmarking requires comparable data – a ‘like for like’ comparison, e.g. for surface treatment activities this would be best achieved on a surface area treated basis or other consumption or throughout basis that is meaningfully process-related. The detail of the benchmarking, including the issues to be benchmarked will depend on the consumption.

### **Economics**

Use of the data to optimise the plant environmental performance will usually achieve economic optimisation.

### **Driving force for implementation**

Benchmarking is also commensurate with good economic performance. Benchmarking and optimising environmental performance (such as raw material, water and power inputs, as well as material losses) will achieve economic optimisation at the same time.

A solvent management plan is the only way to calculate the fugitive and total emissions from an installation and is required under the IED for all the activities covered in this document.

### **Example plants**

No data submitted.

### **Reference literature**

[59, EIPPCB, 2006] [43, Envirowise, 1998] [38, TWG, 2004] [78, TWG, 2005]

## **17.1.5 Costing environmental benefits and estimating cross-media effects**

### **Description**

The concept of BAT under IED takes into account the likely costs and benefits of techniques. An objective of the integrated approach is to stop the shifting of pollution from one medium to another by selecting techniques or combinations of techniques that are the most effective in achieving a high level of protection of the environment taken as a whole. This is complementary to seeking ongoing improvements in the installation (see Section 17.1.2).

When selecting techniques, if there is only one environmental objective, with one pollutant and few consumption and emission points to be taken into account, the cost efficiency analysis is a straightforward exercise. It is sufficient to rank possible abatement measures based on their marginal costs and reduction potential, and to select the cheapest measure or combination of measures that realise the environmental objective. Usually, the analysis involves multiple consumption and emission points, pollutants, abatement measures, interactions and trade-offs. The least expensive solution cannot be determined easily.

The ECM REF provides guidance on assessing cost and benefits, as well as guidance on assessing techniques that are most effective in achieving a high level of environmental benefit as a whole (i.e. have the lowest cross-media effects).

Some guidance and models have been developed to assist in assessing costs and environmental benefits. Examples are given in Annex 21.3.

### **Achieved environmental benefits**

Assists with identifying the most cost-effective options.

### **Cross-media effects**

Assists with identifying the techniques or combinations of techniques with the lowest cross-media effects.

### **Operational data**

No data submitted.

### **Applicability**

The extent of this exercise will depend on the installation size, and the number of the variables. A full cross-media study is carried out infrequently. See Section 17.1.2.

When using models to assist with decisions, it is essential to:

- understand the objectives for the model to ensure it will provide the assistance required. For example, is it a tool to inform policy, or for assessing cross-media effects and/or cost-effectiveness at an installation level, or is to inform national policy making;
- check for any assumptions made;
- ensure that the model results are presented in a form compatible with other data being considered, e.g. costs are annualised, or based on a production or emission measure that is readily comparable (see the ECM REF for advice);
- understand that models are unlikely to contain data on all the BAT options or techniques to be considered (including new ones not listed in this document) so more options may be available;
- assess the consumption as well as the emissions. This is usually most important for energy (and therefore CO<sub>2</sub>), and in some cases SO<sub>x</sub> and NO<sub>x</sub> emissions.

When considering options at an installation level, it is important to consider other factors that will influence choices. Some of these are listed in the introduction to Chapter 21, e.g. factors affecting the speed of implementation, quality and customer specifications, etc.

### **Economics**

Assists with identifying the most cost-effective options.

### **Driving force for implementation**

Assists with identifying the most cost-effective options. Other legislation such as IED, WFD, etc. Models such as EGTEI and MKM (VITO) are aimed at producing costs of emission reduction techniques and cost benefits for various activities, regional and national scenarios, and provide data for RAINS.

### **Example plants**

Examples are given in the ECM REF. Examples of models are given in Annex 21.3.

### **Reference literature**

[48, VITO, 2005, 50, COM, 2005, 81, EGTEI, 2005, 82, EGTEI, 2005] [78, TWG, 2005].



## 17.2 Storage and handling of solvents

### ~~Installation design, construction and operation (including good housekeeping)~~

This section covers the areas and activities of the installation that are not covered elsewhere, in particular the prevention of emissions to soil, groundwater and surface water, although the techniques are also relevant to the prevention of fugitive emissions to air. However, when considering the integrated operation and the complexity of an IED installation, overlaps and repetition with other sections are inevitable: these have been cross-referenced where found.

Design, construction and operation (sometimes referred to as good housekeeping or good practice) to prevent spillages and leakages are described extensively elsewhere, such as generally in the EFS BREF [44, COM, 2005], in national guidance documents [69, RIZA, 1999], [70, INRS, 1998] as well specifically for this sector [42, Envirowise, 2003]. The following sections are therefore a brief summary of key issues for this sector, together with more specific information relevant to the scale and type of operations.

### ~~Safe storage of hazardous substances and prevention of unplanned releases~~

**Description:** ~~A planned, integrated approach can decrease environmental accidents, or unplanned releases, starting with the identification of those aspects of an installation that may have significant impacts on the environment. The identified risks are then tackled by careful design and construction, as well as by management systems that address the prevention, mitigation and management of accidents and emergencies, and the breaches of permit conditions.~~

~~Regulatory and/or good practice systems for pollution prevention are in use in some countries. Many installations in the sector have benefited from the introduction of such techniques. The following activities are key examples where these techniques reduce the frequency and impacts of acute and chronic pollution not only to the air, but also to surface and groundwaters; and soil. They also assist in making the operations more cost effective:~~

- ~~• routine and non routine maintenance including maintenance of covers and pipe joints for solvent storage and delivery systems~~
- ~~• delivery and storage of raw materials~~
- ~~• process control, process and environmental monitoring.~~

~~Some key aspects for preventing pollution are:~~

- ~~• the identification of hazards and pathways~~
- ~~• a simple ranking of hazard potential.~~

~~A three step implementation of actions for pollution prevention:~~

~~*Insert 3 steps from old BAT 15, as a better summary*~~

- ~~• primary measures (structural):~~
  - ~~○ sufficient plant dimensions~~
  - ~~○ selection of sealing materials where chemicals are stored or handled, e.g. for flooring, contained areas (see secondary measures, below)~~
  - ~~○ stability of the process line and components (including temporary and infrequently used equipment, such as pumps and tanks used for occasional maintenance operations).~~
- ~~• secondary measures (plant or equipment):~~
  - ~~○ containment (or secondary containment) refers to additional protection against storage tank releases over and above the inherent protection provided by the tank container itself (in this sector, the tanks may be for storage or production). There are two major types of secondary containment for leakages, namely those that are part of the tank~~

construction, such as double tank bottoms (only for aboveground tanks), double skinned and double walled tanks and impervious barriers which are placed upon the soil surface below the tanks, and ensuring that routes to sewers or groundwater are isolated or minimised, e.g. by ensuring access hatches (manholes) are effectively sealed against the solvents in use, open drains are closed and sealed, etc.

- correct specification of size and strength of tanks or storage containers to receive pumped out liquors (see also stability, in primary measures, above), or a self safe volume control system is installed
- leak identification systems
- tertiary measures (management systems):
  - inspections by external experts and internally including regular maintenance
  - emergency plans for potential accidents
  - test programmes.

The identification of measures and targets for the environmental effects can determine the choice of site, plant and equipment as well as design and construction of the infrastructure and plant.

**Achieved environmental benefits:** Helps minimise fugitive emissions to air. Particularly useful in minimising contamination of soil and groundwater by routes that are not readily visible and are difficult to identify. Facilitates site decommissioning. Minimisation of unplanned chronic and acute discharges to surface waters as well as municipal waste water treatment systems.

**Cross-media effects:** No adverse implications.

**Operational data:** Careful planning and design utilising operational experience can make routine operation, maintenance and monitoring easier, cheaper and environmentally safer.

**Applicability:** These measures can be considered for all installations; however they are best implemented at the proposal and initial design and build stages. Many changes can be incorporated in major upgrades, while some improvements can be made to existing installations during normal maintenance periods, although retrospective improvement may be more difficult, and may not be as effective. Various standards and guidance can also form part of longer term planning for plant improvements.

**Economics:** These are part of the investment costs with initial investments or upgrades. Some techniques may be no cost options at a new build or upgrade stage. Often costs can be recovered by more efficient working, maintenance, and the avoidance of costs for dealing with accidents and breaches of permit.

**Driving forces for implementation:** Business duty of care and possible liability for any environmental damage arising. The Seveso Directive (as amended), where relevant substances and quantities are stored.

**Example plants:** Widely used in many countries.

**Reference literature:** [44, COM, 2005] [59, EIPPCB, 2005] [69, RIZA, 1999] [61, Eurofer, 2003] [70, INRS, 1998] [187, EC, 1996] [78, TWG, 2005]

## 17.2.1 Planning for the prevention and control of leaks and spillages

### Description

Preparation and implementation of plans for the prevention and control of potential spillage incidents/accidents

### Technical description

This includes but is not limited to:

- site incident plans for small and large spillages;
- identification of the roles and responsibilities of persons involved;
- ensure staff are environmentally aware and trained to deal with spillages and accidents (see 17.2.6);
- identify areas at risk of spillage and leaks of hazardous materials and rank according to the risk; this includes any possible access to sewers, such as drains and inspection hatches;
- in identified areas, ensuring suitable containment systems are in place, e.g. impervious floors and containment barriers are in place and in good order;
- identification of suitable spillage containment and clean-up equipment and regularly ensuring it is available, in good working order and close to points;
- waste management guidelines for dealing with waste arising from spillage control.

See also Section 17.2.7 for inspections and maintenance.

#### **Achieved environmental benefits**

Prevents or minimises the contamination of surface waters, groundwaters and soils, and assists in site decontamination on cessation of activities. Also reduces fugitive emissions from solvent spillages.

#### **Environmental performance and operational information**

Small spills are likely to happen more often and the sum effect of these if not detected and dealt with is significant increases of fugitive emissions to air, soil and groundwater.

Impacts of spills in risk areas can be minimised in advance, e.g. by:

- sealing drains and inspection hatches to sewers;
- ensuring areas where solvents are stored are bunded and sealed with impermeable barriers and floors;
- providing catch pits where solvents are regularly used, e.g. cleaning areas.



Source: [Amcor Flexibles Europe and Americas, HP Laminates, Ghent, BE]

**Figure 17.1: Spill kit in place in transit area between store and production zones**

### Cross-media effects

No adverse implications.

### Technical considerations relevant to applicability

The scope (e.g. level of detail) and nature of emergency plans will generally be related to the nature, scale and complexity of the installation and raw materials used, and the range of environmental impacts it may have.

### Economics

Staff time for training and updating plans.  
Materials for spillage and clean-up.

### Driving force for implementation

Reduced risks of liability from contamination  
Reduced risks of associated accidents, e.g. preventing slippery floors, risk of fire.

### Example plants

Amcor, Gent, BE. Widely used.

### Reference literature

[180, COM, 2017] Site visit report, Amcor, Gent, May 2107.

### Storage and handling of chemicals, hazardous materials and waste

*Combined with 20.2.1 and 20.2.2.1*

**Description:** The storage and handling of hazardous materials is described in detail in the ESB BREF [44, COM, 2005]. Storage and handling of hazardous materials is necessary to maintain the supply of materials to the treatment application systems.

**Achieved environmental benefits:** Storage areas and handling in purpose built rooms and with appropriate equipment reduces environmental risks.

**Cross-media effects:** None.

**Operational data:** The following techniques are important for this sector:

- only small quantities are stored directly in the application areas. For larger quantities, separate rooms are necessary to reduce fire and environmental hazards
- bulk storage tanks for solvents and liquids containing solvent can be back vented to the delivery tank during filling or vented through carbon absorption. Back venting may only account for 0.01 to 0.03 % of the amount of solvent passing through the tanks, and is only likely to be considered where it can achieve better benefits
- provide containment for accidental spills (e.g. 'catch pans' for small scale spills), provide adsorbent material at sensitive locations
- underground storage of hazardous materials has a high risk of unplanned leakage which can contaminate soil and groundwater, as well as unobserved emissions to air. This may be avoided by using aboveground storage, or where underground storage is used, by using double-skinned construction and/or leakage detection systems
- all fixed bulk storage tanks should be fitted with audible and/or visual high level alarms or volume indicators to warn of overfilling. Where practicable in relation to the viscosity of the material being handled or pumping system used, the filling systems should be interlocked to the alarm system to prevent overfilling
- unique filling points for each tank to avoid cross-contamination of (especially incompatible) materials.

For large tanks, techniques can be found in the ESB-BREF. In particular, techniques to increase reflectivity and reduce heat absorption from solar radiation and therefore reduce losses of solvent by evaporation include:

- paint aboveground tanks white or install a sunscreen or solar shield
- use cone roof tanks with internal floating covers (depending on the frequency of emptying).

**Applicability:** Special storage for hazardous materials is widely applied as a regulatory requirement or good practice. See back-venting in Operational data, above.

**Economics:** No data submitted.

**Driving forces for implementation:** Complying with legal requirements for health and safety and for the prevention of accidents. It must be noted that there are differing national regulations within Europe.

**Example plants:** Applied in all industries in the scope of this document.

**Reference literature:** [38, TWG, 2004] [71, UK DEFRA and notes, 2003] [68, ACEA, 2004, 44, COM, 2005] [78, TWG, 2005]

## 17.2.2 Storage and handling [and use] of solvents in production areas

### 17.2.2.1 Sealing or covering of containers

#### Description

Store solvents, hazardous materials, waste solvents and waste cleaning materials in sealed or covered containers suitable for the associated risk and designed to minimise emissions.

#### Technical description

Where VOC solvents are used, the following general measures and principles can be applied to ensure they are kept in airtight (or nearly airtight) containers:

- enclosure, e.g. using lids, of the sources of potential emissions;
- re-lid partly emptied drums or cans of solvent to prevent vapour losses;
- keep solvent containers away from sources of heat and draughts (e.g. movement of fork lift trucks near open containers) to minimise evaporation;
- encapsulate vessels, reservoirs and machinery as much as possible, using well-fitting sealed lids and covers;
- where vessels and reservoirs do not have proper covers, use plastic wrap or antistatic plastic covers, where necessary attached by elastic bands, tyre inner tubes, or nylon hook and loop fasteners (where these materials are not dissolved by the solvent being covered); such covers have the added advantage of keeping them free from dust and debris;
- store wastes containing solvents, e.g. contaminated wipes and solvent-based residues, in containers (see also Section 17.10.2.8).

#### Achieved environmental benefits

Reduced amount of VOCs emitted to the air.

#### Environmental performance and operational information

Note that many solvents expand and contract significantly with changing ambient temperatures. Sufficient space should be allowed for this in the storage vessel, according to the solvents used, e.g. containers should allow about 10 % redundant volume.

#### Cross-media effects

No information provided.

**Technical considerations relevant to applicability**

Health and safety at work issues may determine whether and how the solvent container is covered.

**Economics**

No information provided.

**Driving force for implementation**

Workplace health and safety.

**Example plants**

**Reference literature**

[38, TWG, 2004] [89, UK and Programme, 1996] [59, EIPPCB, 2005][78, TWG, 2005]

**17.2.2.2 Minimisation of storage of hazardous materials in production areas**

**Description**

Hazardous materials should be present in production areas only in amounts that are necessary for production, storing larger quantities separately.

**Technical description**

Materials containing solvents should be limited to the current production needs and next change-overs. Full or partly empty containers from previous production runs should be removed to storage areas. Only cleaning materials for the current production and the next change-overs should be in the production areas.

**Achieved environmental benefits**

Reduces the risks of accidental spillages by movements of staff, lifting equipment, etc.  
Assist accounting for solvent-containing materials for solvent mass balances (see Section 17.3.1).

**Environmental performance and operational information**

**Cross-media effects**

**Technical considerations relevant to applicability**

**Economics**

Staff time in moving containers.

**Driving force for implementation**

Assists meeting health and safety objectives.

**Example plants**

**Reference literature**

No information provided.

**17.2.2.3 Minimisation of the amount of materials stored  
Just-in-time management**

*TWG: What benefits does JIT deliver?*

**Description**

Minimise quantities of solvents and solvent-containing materials stored in the plant by using just-in-time inventory management and ensuring that quantities ordered match the need.

### **Technical description**

Applying a just-in-time management system will ensure that the ordered amount of materials, e.g. paint or ink, which are to be used for a specific job, matches the volume that is needed. For example, the ordered amount of paint of a certain colour matches the volume needed for a certain strip to be coated. This applies to external suppliers, and does not include the in-house preparation of batches of inks, paints, etc.

**Achieved environmental benefits:** Less waste materials will arise and fewer raw materials are used.

### **Environmental performance and operational information**

#### **Cross-media effects**

This type of management system transfers the environmental burden onto the supplier. It involves the manufacture of smaller batch sizes and increased transportation.

#### **Technical considerations relevant to applicability**

Paint management systems are commonly applied in coil coating plants, vehicle paint shops and wood coating.

#### **Economics**

Cost reduction by optimised logistics.

#### **Driving force for implementation**

Cost reduction.

#### **Example plants**

All automotive plants.

#### **Reference literature**

[22, ECCA, 2004] [38, TWG, 2004] [78, TWG, 2005]

## **17.2.3 Pumping and handling liquids**

### **17.2.3.1 Prevention of leaks and spillages during pumping**

#### **Description**

Ensure that pumps, pipework (especially temporary piping) and associated equipment (e.g. containers) are properly secured and maintained. Use only pumps suitable for solvents.

#### **Technical description**

It is essential to ensure that pumps, pipework (especially temporary/flexible piping) and the associated equipment (e.g. receiving containers) are properly secured and maintained.

Only pumps suitable for solvents, i.e. flameproof and with solvent resistant seals should be used.

Where possible, avoid manual handling by pumping solvents and solvent-based materials through a piped system (e.g. ring main) to the point of use. The advantages include:

- reduced risk of spillage during transfer and decanting;
- better containment and lower risk of exposure to contaminants;
- ability to fit flow-meters to allow accurate auditing.

**Achieved environmental benefits**

Prevents or minimises the contamination of surface waters, groundwaters and soils, and assists in site decontamination on cessation of activities. Also reduces fugitive emissions from solvent spillages.

**Environmental performance and operational information**

**Cross-media effects**

None

**Technical considerations relevant to applicability**

Training and good supervision are required to ensure that staff do not carry out pumping operations in haste and without due care.

**Economics**

**Driving force for implementation**

Reduced risks of liability from contamination.

Workplace health and safety objectives including reduced risks of associated accidents, e.g. preventing slippery floors, reducing risk of fire.

**Example plants**

**Reference literature**

[38, TWG, 2004] [71, UK DEFRA and notes, 2003] [68, ACEA, 2004, 44, COM, 2005] [78, TWG, 2005]

**17.2.3.2 Prevention of overflows during pumping**

**Description**

**Technical description**

Ensure receiving tanks are:

- of sufficient size to accept the quantity pumped;
- bulk storage tanks are fitted with audible and/or visual high-level alarms, with shut-off systems if necessary;
- for smaller quantities, ensure containers are correctly positioned to receive the flow and the pumping operation is supervised

**Achieved environmental benefits**

Prevents or minimises the contamination of surface waters, groundwaters and soils, and assists in site decontamination on cessation of activities. Also reduces fugitive emissions from solvent spillages.

**Environmental performance and operational information**

**Cross-media effects**

None

**Technical considerations relevant to applicability**

**Economics**

**Driving force for implementation**

Reduced risks of liability from contamination.



Workplace health and safety objectives including reduced risks of associated accidents, e.g. preventing slippery floors, reducing risk of fire.

### **Example plants**

#### **Reference literature**

No reference literature provided.

### **17.2.3.3 Prevention of VOC vapour releases during delivery**

#### **Description**

When pumping solvents/solvent-containing materials in bulk (e.g. loading or unloading of tanks), the vapour displaced from receiving tanks should be captured, with or without destruction (i.e. vapour recovery system, back-venting).

#### **Technical description**

Pumped solvents or solvent containing liquids will displace solvent vapours from receiving tanks. These can be captured and:

- vented back to the discharging tank (vapour recovery system, back-venting);
- adsorbed and recovered or destroyed;
- vented into a WGT system.

#### **Achieved environmental benefits**

Reduction of fugitive solvent emissions to air.

#### **Environmental performance and operational information**

#### **Cross-media effects**

#### **Technical considerations relevant to applicability**

Back-venting may only account for 0.01 to 0.03 % of the amount of solvent passing through the tanks, and is only likely to be considered where it can achieve better benefits.

#### **Economics**

#### **Driving force for implementation**

#### **Example plants**

#### **Reference literature**

No reference literature provided.

### **17.2.3.4 Containment for spills when moving solvents**

#### **Description**

When moving solvent materials in containers, possible spills are avoided by providing containment or rapid take-up, e.g. by using trolleys, pallets and/or stillages with built-in containment (e.g. 'catch pans')

#### **Technical description**



**Figure 17.2: Built-in containment for moving and storing drums in production areas**

### Achieved environmental benefits

Prevents or minimises the contamination of surface waters, groundwaters and soils, and assists in site decontamination on cessation of activities. Also reduces fugitive emissions from solvent spillages.

### Environmental performance and operational information

#### Cross-media effects

#### Technical considerations relevant to applicability

#### Economics

#### Driving force for implementation

Reduced risks of liability from contamination.  
Workplace health and safety objectives including reduced risks of associated accidents, e.g. preventing slippery floors, reducing risk of fire.

#### Example plants

#### Reference literature

No reference literature provided.

## 17.2.4 Minimisation of raw material consumption

See also Section 17.12 on waste minimisation and treatment.

### 17.2.4.1 Advanced mixing systems

*ESVOC propose deletion, but this technique is applied e.g. in flexo – site visit at AMCOR*

#### Description

Computer-controlled mixing equipment to compose the desired paint/ coating/ ink

#### Technical description

When using automated mixing systems, it is not strictly necessary to use standard colours to mix the required colour. Specific colours can be composed from non-standardised colours by computer-controlled equipment. This, however, requires very sophisticated software and exact knowledge of the non-standardised colours which are to be used for the mixing. For this purpose, these non-standardised colours need to be measured with a photo spectrometer and the result is introduced to the colour-computer.

For example, with an online mixing system for two-component products such as paints or adhesives, the exact amount needed will be dosed and mixed immediately before usage. The mixing unit is not a part of the paint or adhesive application tool. It is a standalone unit.

It is possible to obtain similar proportional benefits from using programmable scales or computerised Pantone colour matching systems.

#### **Achieved environmental benefits**

Reduction in waste materials and saving of resources. During manual mixing, losses of 1 % or 2 % of solvents can occur. These can account for 15 % of the total VOC emissions. Automated mixing in enclosed machines reduces most of these emissions. Also, less cleaning agent is needed.

In printing, the amount of waste ink may be reduced by 75 % depending on the number of times that inks are mixed and the amounts involved. The automated technique permits a perfect dosage so that no colour correction is necessary, so therefore, only the exact quantity of ink is prepared.

With an online mixing system for two-component products, reductions of 10–30 % of waste can be achieved.

#### **Cross-media effects**

Automation requires energy.

#### **Operational data**

This working method also makes it possible to use paints or inks that have returned as an ingredient for new paints or inks (see Section 17.12.2). The return paints or inks are mixed according to the approximate colour, i.e. light greens, dark greens, light reds and dark reds. Once a certain quantity is achieved, the resulting colour is measured and the computer is told to use that colour whenever possible.

#### **Applicability**

Commonly applied in flexo and packaging gravure for solvent-based inks, where more than 200 tonnes of press-ready ink per year is mixed.



*Source: Amcor Flexibles Europe and Americas, HP Laminates, Ghent, BE*

**Figure 17.3: Automatic mixing system in flexography plant**

In the coil coating industry, automated colour mixing is routinely carried out in the paint making factories, and the application is offered to the coil coating lines, but it is not always appropriate. It depends on the colour and product mix. There are examples of coil coating lines using in-house computer controlled colour mixing schemes.

Online mixing systems for two-component products are applicable when produced on equipment dedicated to a single product line. There is no restriction in subsequent application techniques. In the Netherlands, companies are advised to apply this technique when over 2000 litres of two-components paint needs to be mixed. For adhesives, relatively small amounts are mixed. It is commonly applied in wood and furniture painting. It is also applicable to the coating of trains, e.g. for applying the groundcoat and primer/filler.

#### **Economics**

In printing, the investment cost depends on size and exact requirements, starting at approximately EUR 50 000. However, a saving will be incurred for the operation because less ink is used and less waste needs to be disposed of. Depending on the size of the operation, the savings may lead to a favourable payback time for the investment.

For online mixing systems for two-component products, investment costs are EUR 9 000–18 000 for a mechanically driven installation used for the mixing of base coat. The costs are EUR 27 000–37 000 for an electronically driven installation. The payback time will normally be several years for companies coating small series. However, this depends on the amount of waste prevented, the price of the materials that are mixed and the costs for disposal.

#### **Driving force for implementation**

The driving forces for implementation are the automated mixing rather than avoidance of waste. In adhesive application, automation is the main driving force.

### Example plants

No data submitted.

### Reference literature

[4, Intergraf and EGF, 1999] [18, UBA Germany, 2003] [27, VITO, 2003] [13, DFIU and IFARE, 2002] [38, TWG, 2004]

### Reuse of returned paints or inks

*ESVOC propose deletion*

### Reuse of recovered coatings or inks

*ESVOC propose deletion*

#### 17.2.4.2 Centralised ink / paint / coating / solvent supply [Direct piping of paint or ink from storage]

*ESVOC proposed combine with 20.6.3.3 and 5, pig-cleaning systems.*

##### Description

Supply of paints and solvents (for viscosity adjustment) to the application point by direct piping with ring lines, including system cleaning such as by pigging or air flushing.

~~Paint or ink is transported from the storage area directly to the painting or inking units through piping systems.~~

##### Technical description

Paints or inks, and solvents for viscosity control are piped directly from the storage area to the painting or inking units.

##### Achieved environmental benefits

Virtually closed systems with low VOC emissions and avoiding spillages during transfer and decanting.

##### Environmental performance and operational information

For better control, aboveground piping should be installed, as underground pipes for solvents are a known source of serious soil and groundwater pollution.

Operating with pigging or air flushing optimises the benefits in materials saving and reducing VOC emissions.

Reducing the risk of staff exposure to contaminants.

Makes fitting of flow meters easier, to allow accurate auditing and more accurate calculation of the solvent mass balance.

Fewer waste paints or inks, fewer containers and fewer materials to clean. For example, the achievable level of residues for heatset plants is < 1 % of the purchased ink.

The system is effective if coupled with regular inspection and maintenance. Otherwise, solvent losses from pumps, valves and flanges may add up and become a significant source of VOC emissions.

##### Cross-media effects

No data submitted.

### Technical considerations relevant to applicability

Direct piping is applied in large plants where large reusable paint or ink containers are used.

Widely used in the automotive industry.

In printing, it is applicable to plants with sufficient ink consumption; commonly applied in large heatset plants. In publication gravure, this is a standard technique. Only toluene is used and, therefore, direct supply is easy to apply. However, in flexible packaging printing, the situation is more complex because of the many hundreds of different colours that are used. Since the viscosity control needs to be done with different solvents depending on the job in hand. Generally ethanol (for flexo) or ethyl acetate or specific ethanol/ethyl acetate mixtures (for gravure) and sometimes MEK (for adhesives and paints) and sometimes even other solvents are used.

Commonly applied in the coating of wood and furniture when larger volumes of paint are used. Not applicable in the coil coating industry.

### Economics

*TWG please clarify*

For new plants this is a low-cost item; however, retrofit is very expensive.

The investment in piping and pumps is considerable. For example, for the printing industry, the minimum investment ranges from EUR 5 000–24 000. Minimal savings are incurred through slightly cheaper ink and less disposal costs.

### Driving force for implementation

Decreases the time that the painting or inking units are not running.

### Example plants

No data submitted.

### Reference literature

[4, Intergraf and EGF, 1999] [18, UBA Germany, 2003] [38, TWG, 2004] [89, UK and Programme, 1996] [78, TWG, 2005]

### Direct piping of solvents from storage

*Combined with: Centralised ink/paint/coating/solvent supply, above*

**Description:** Solvents for viscosity control are piped directly from the storage area to the painting or inking units. For better control, aboveground piping should be carried out as underground pipes for solvents are a known source of serious soil and groundwater pollution.

**Achieved environmental benefits:** Piped systems have a number of advantages, which are:

- reducing the risk of spillage through transfer and decanting
- removing the need to uncover tanks and reservoirs, allowing better sealing and reducing the risk of exposure to contaminants
- being able to fit with flow meters to allow accurate auditing.

**Cross-media effects:** No data submitted.

**Operational data:** In publication gravure, only toluene is used and, therefore, direct supply is easy to apply. However, in flexible packaging printing, the situation is more complex since the viscosity control needs to be done with different solvents depending on the job in hand. Generally ethanol (for flexo) or ethyl acetate or specific ethanol/ethyl acetate mixtures (for

gravure) and sometimes MEK (for adhesives and paints) and sometimes even other solvents are used.

Piping without metering can make the measurement of solvent consumption in some specific parts of the process impossible. This reduces the amount of data available for the solvent management plan and makes identification and quantification of fugitive emissions more difficult.

**Applicability:** Commonly applied in publication gravure and flexible packaging printing processes. Widely used in the automotive industry. Not applicable in the coil coating industry. Commonly applied in the coating of wood and furniture when larger volumes of paint are used, i.e. in medium sized or larger companies.

**Economics:** For new plants this is a low cost item; however, retrofit is very expensive.

**Driving force for implementation:** Besides reducing solvent use and emissions, it also decreases the time that the painting or inking units are not running.

**Example plants:** No data submitted.

**Reference literature:** [18, UBA Germany, 2003] [38, TWG, 2004] [89, UK and Programme, 1996] [78, TWG, 2005]

#### 17.2.4.3 Ink / paint / coating / solvent supply at point of application

*TWG please provide more information*

##### Description

Supply of paints and solvents from small transport containers placed near the application zone ( spray booth, printing press, etc.).

##### Technical description



Source: Tata Steel, Maubeuge, FR, 2017

Figure 17.4: Paint supply at coating head in coil coating

#### Environmental performance and operational information

##### Cross-media effects

## Technical considerations relevant to applicability

### Economics

### Driving force for implementation

### Example plants

### Reference literature

#### 17.2.4.4 Pig-clearing systems

*ESVOC proposal: "Combine with 18.6.4.4". On-site paint supply: This technique is also mentioned in Section 17.2.4.2*

##### Description

This method only fills as much paint into the system as necessary for the coating processes. The paint is pressed back from the (flexible) tube into the paint supply by an elastic separation module (pig-clearing) and is reused. The purged solvents can be recovered and reused.

A special type of purging is called 'soft purging', where lower VOC paint materials, rather than solvent are used to purge guns and lines.

##### Achieved environmental benefits

The advantages are the lower use of cleaning agents, the reduction of paint and solvent losses as well as the decrease of the manual processes with the colour change.

##### Cross-media effects

No data submitted.

##### Operational data

No data submitted.

##### Applicability

Only applicable where:

- paints or inks are delivered to machinery through pipes;
- different colours are sent through the same pipe regularly.

Not applicable where low viscosity products are used as they will run past the module. Currently applied in some base coat lines of automotive paint shops.

In the automotive industry, the trend towards more special colours has initiated the development of new lacquer supply systems allowing an economic change in colours. Also soft purging is applied.

In the furniture industry, there is also an increasing demand of furniture painted in individual and special colours and consequently the use of pig-clearing systems.

This technique is not commonly applied in the coating of trains.

##### Economics

Reduction of costs for paint and solvent consumption.

##### Driving force for implementation

No data submitted.

### Example plants



Volkswagen AG, Wolfsburg, Germany; and Renault, Flins sur Seine, France.

### Reference literature

[13, DFIU and IFARE, 2002] [68, ACEA, 2004] [38, TWG, 2004] [78, TWG, 2005]

## 17.2.5 Automation of equipment

### Description

Many operations in an installation may be automated, depending on the activity and the industry such as spraying, roller coating and curtain coating, colour mixing, colour changing, piping delivery of solvents and solvent-based materials, and cleaning

### Technical description

Many operations in an installation may be automated, depending on the activity and the industry. Examples are:

- robot spraying of:
  - vehicles, see Section 2.2;
  - of plastics, see Section 3.2;
- automatic colour changers for vehicle coating, Section 2.2;
- printing, applicable to automatic mixing systems, see Section 17.2.4.1, flexible packaging only;
- roller coating, see Section 17.7.3.1;
- curtain coating see Section 17.7.3.5;
- piped delivery of solvents and solvent-based materials (see Sections 17.2.2, 0 and 0).

Examples are:

- robot spraying:
  - of cars, see Sections ~~Error! Reference source not found.~~ and ~~Error! Reference source not found.~~
  - of trucks see Section ~~Error! Reference source not found.~~
  - of ships, see Section 4.4.4
  - of plastics, see Section ~~Error! Reference source not found.~~
- automatic mixing systems, see Section 17.2.4.1
  - for printing, applicable to flexible packaging only (see Section ~~Error! Reference source not found.~~)
- automated colour change, see Section
- roller coating, see Section 17.7.3.1
- curtain coating see Section 0
- piped delivery of solvents and solvent-based materials (see Sections 17.2.2 0 and 0).

### Environmental performance and operational information

According to technique: Minimises overspray, optimises application and layer thickness (for painting), reduces dust, materials efficiency increased and waste reduced, reduces cleaning requirements, less waste solvent, etc.

### Technical considerations relevant to applicability

See relevant sections.

### Cross-media effects

See relevant sections.

### Operational data

See relevant sections. See example plant below (~~See Error! Reference source not found.~~ and ~~Error! Reference source not found.~~).

**Applicability**

See relevant sections. Widely used in car painting. Used in painting aircraft parts.

**Economics**

See relevant sections. For savings in materials and time in vehicle painting, see

**Driving force for implementation**

Increased quality and productivity.

**Example plants**

See relevant sections.

Aircraft parts: Airbus, Nantes, France, Airbus, Broughton, UK.

Vehicles: Seat Martorell, Spain; VW Pamplona, Spain, and VW, South Africa; Renault, Flins, and Douai, France; ~~BMW, powder clear coat with ESTA, Munich, Germany; Mercedes, Germany.~~

**Is this example valid now?****Table 17.2: Example for the introduction of interior robot spraying on a car assembly line**

<b>Upper medium class car, 500 units per day. Interior painting:</b> 145 ml front door, 130 ml rear door, 255 ml engine compartment, 150 ml trunk. The paint costs EUR 10/l. NB: No other baseline data are given		
<b>Conversion from manual air spray to:</b>	ESTA	From air automated to ESTA robots
<b>Paint saving:</b>	138 000 l/yr 1.2 l/unit	60 950 l/yr 0.53 l/unit
<b>Cost saving per year:</b>	EUR 1 380 000/yr	EUR 609 500/yr
<b>CPU (cost per unit) saving:</b>	EUR 12	EUR 5.3
<b>Payback time, paint costs only (ROI)</b>	20 months	13 months
Transfer efficiency: air 30–35 %, ESTA 40–60 % . Path length reduced by up to 60 % . Path speed reduced by up to 25 % . Painting time reduced by up to 25 % . Quality higher due to wrap around. Dust reduced due to reduced air. Coat thickness: same, possibly thicker.		

**Table 17.3: Example for the introduction of exterior robot spraying using metallic paints on a car assembly line**

<b>Upper medium class car, 500 units per day. Metallic painting:</b> Unit painted surface 9.5 m <sup>2</sup> . Base coat two-coat thickness 5 µm, solids content 15 % . The paint costs EUR 10/l NB: No other baseline data are given.	
<b>Paint saving per year Per unit</b>	41 641 l/yr 0.45 l/unit
<b>Cost saving per year CPU (cost per unit) saving</b>	EUR 416410/yr EUR 4.5
<b>Amortisation (ROI)</b>	10 months
<i>Source:</i> [110, Eurocar, 2005]	

**Reference literature**

See relevant sections indicated in the Description above [110, Eurocar, 2005].

**17.2.6 Training**

*ESVOC propose delete*

*Training is an essential part of an EMS and necessary for implementation of many BAT, especially for fugitive emissions control (see Section 17.1.1 (c) ii). BAT 1*

**TWG: Does this cover training for operating, cleaning and maintenance activities adequately?**

#### **Description**

Systematic training of staff in the handling and use of solvent-containing materials, as well as for updates in materials and techniques, accompanied by up-to-date documentation.

#### **Technical description**

Staff carrying out many of the functions and operating equipment need adequate, periodic training. Theoretical and practical training in the handling, use and clean-up of solvents and related equipment is essential. The introduction of new materials and/or techniques/systems require the updating of the skills of operators and support staff.

~~Environmental, economic and health implications can also be emphasised.~~

#### **Environmental performance and operational information**

Systematic, periodic training reduces VOC emissions, loss of other materials, reworking and downtime by maintaining effectiveness of day-to-day handling of materials, especially solvents, and operation of equipment.

Training should also be carried out to accompany significant changes in materials, systems and techniques. Such changes need changed attitudes, which can be prompted by training.

New coating materials and/or systems and techniques often show different characteristics, such as restricted application windows, thus the technical skills of operators and support staff have to be improved, otherwise quality problems are caused, such as film build being too thick.

Written up-to-date documentation for all operations involving the handling or use of solvents should include:

- process manuals to detail the quantities of chemicals required, provide health and safety data and identify the relevant operating procedures;
- operating procedures to explain how to use particular equipment/plants in conjunction with particular solvents or coatings;
- dealing with spillages, etc. (see Sections 17.2.1, 17.2.3).

#### **Achieved environmental benefits**

Reduced VOC emissions. Reduced raw material consumption and waste generation.

#### **Cross-media effects**

None.

~~Operational data: No data submitted.~~

#### **Applicability**

Widely applied.

#### **Economics**

No data submitted.

#### **Driving force for implementation**

Health and safety of employees. Maintains and/or improves product quality and throughput.

#### **Example plants**

No data submitted.

#### **Reference literature**

[89, UK and Programme, 1996]

## Optimisation of processes/equipment

*ESVOC propose delete BAT 1*

**Description:** Most activities require optimising, i.e. the consumption and/or emissions together with other parameters such as quality, throughput, etc. are monitored while certain process variables are changed. Optimisation can start with the design process, and is often carried out by or with the support of process suppliers. In some cases, software programs can be used.

Examples are:

- ~~optimising the design and operation of waste gas treatment by software, see Section **Error! Reference source not found.**~~
- ~~optimising the heatset offset printing for low IPA usage, see Sections **Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.**, etc.~~

**Achieved environmental benefits:** ~~Enables an activity to be optimised for consumption of water, energy and conservation of raw materials, as well as minimising emissions, particularly VOCs.~~

**Cross-media effects:** ~~No data submitted.~~

**Operational data:** ~~Can use existing data and can be used to benchmark performance as well as plan improvements.~~

**Applicability:** ~~All activities.~~

**Economics:** ~~See Driving forces for implementation, below.~~

**Driving forces for implementation:** ~~Environmental optimisation can also optimise the plant's process and economic performance.~~

**Example plants:** ~~Widely applied.~~

**Reference literature:** ~~[59, EIPPCB, 2005]~~

### 17.2.7 Inspection and maintenance to reduce solvent emissions during OTNOC

*This text combines chapters 20.2.6 and 20.11.1.2 of the original BREF*

#### Description

Planned and regular inspection and maintenance directly minimises VOC emissions, in particular by reducing breakdowns and OTNOC, including fugitive leaks of solvent as vapours and liquids.

~~Maintenance of all plants and equipment is essential and forms part of an EMS (see Section 17.1.1 (e) vii).~~

#### Technical description

All equipment and systems handling VOCs need maintenance, both preventative and for breakdowns. Untreated emissions of flue gases and of leaks of liquids can be minimised by:

- planned maintenance of larger repair and replacement tasks;
- regular maintenance checks.

The maintenance plan for the off-gas extraction and treatment equipment includes regular inspection, preventive and corrective actions to ensure that the off-gas extraction and treatment equipment operates according to its specifications and with their optimal efficiency and minimises the occurrence, duration and impact of OTNOC.

### **Environmental performance and operational information**

Defects in WGT can give rise to VOC emissions of up to 0.4 % of annual VOC inputs per day of OTNOC.

Preventative measures to reduce OTNOC and unplanned emissions:

A preventative maintenance system should be used to e.g.:

- ensure maintenance requiring the switching off of emissions control equipment/systems (e.g. containment, extraction systems, WGT) is planned to take place when:
  - there are no emissions (e.g. shut down times) or when emissions levels are low;
  - during periods when emissions will have least impact, i.e. for VOC emissions, during periods of low sunlight levels, low probability of inversion layers, etc.; this is dependent on weather, time of year and local conditions;
- replacement of parts that require replacement on a regular basis is planned to take place before breakdowns are likely;
- ensure parts that are essential to the normal running of emission control equipment are kept in stock, can be replaced or repaired rapidly with minimum call off times;
- routine and non-routine maintenance including maintenance of covers and pipe joints for solvent storage and delivery systems.

### Regular maintenance checks

Keep a maintenance schedule and record of all inspections and maintenance activities:

- visually check for leaking seals, flanges, valves, welds, tanks and bunds;
- inspections by external experts where necessary;
- monitoring key equipment for problems such as vibration, emission leaks and planning repairs (as above);
- test programmes e.g. pressure-test pipelines and tanks, calibration of metering and monitoring equipment;
- check the tightness of nuts and bolts;
- check for wear and tear on machinery, valves and bunds, over-heating bearings, etc.;
- recalibrate metering systems;
- ensure that extraction and abatement equipment is fully serviceable, and that:
  - dryers or ovens are not leaking;
  - ducting is not leaking;
  - bypasses are in good working order (i.e. not jammed).

### Unplanned maintenance.

~~Where possible, the preventive maintenance programme should be organised and supported by computer software. By flagging up planned maintenance on a daily basis until it is completed, preventive maintenance software can help to ensure that no maintenance jobs are forgotten.~~

Process operators and maintenance staff should identify and report leaks, broken equipment, fractured pipes, etc. to focus unscheduled maintenance.

### **Achieved environmental benefits**

Reduction in overall emission loads. Generally, defects in WG incineration equipment can give rise to VOC emissions equivalent to 0.4 % of the annual input per day (based on 250 working days/year).

### **Cross-media effects**

None.

**Operational data**

No data submitted.

**Applicability**

Generally applied.

**Economics**

No data submitted.

**Driving force for implementation:**

Reduces downtime. Assists in maintaining product quality and throughput. Supports health and safety objectives.

**Example plants**

Widely applied in this sector.

**Reference literature**

[89, UK and Programme, 1996] [78, TWG, 2005].

WORKING DRAFT IN PROGRESS

## 17.3 Monitoring

When considering monitoring, the monitoring REF (MON) [113, EIPPCB, 2003] gives guidance and lists appropriate sources of standards procedures to use for issues including:

- direct monitoring, accounting for total emissions including monitoring of fugitive and diffuse emissions, surrogate parameters and mass balances;
- timing of sampling;
- how to deal with uncertainties.

### 17.3.1 Mass balances for solvents

*TWG please provide additional information*

*Intergraf: compilation of solvent balances to establish consumption and releases of VOCs of an installation at regular intervals*

#### Description

The compilation, at least on an annual basis, of organic solvent inputs and outputs of the plant as defined in Part 7(2) of Annex VII to Directive 2010/75/EU.

As part of understanding the environmental footprint/management plan of an installation (see Section 17.1.2), an operator needs to know:

- how much solvent is used and where;
- how much solvent is emitted and where.

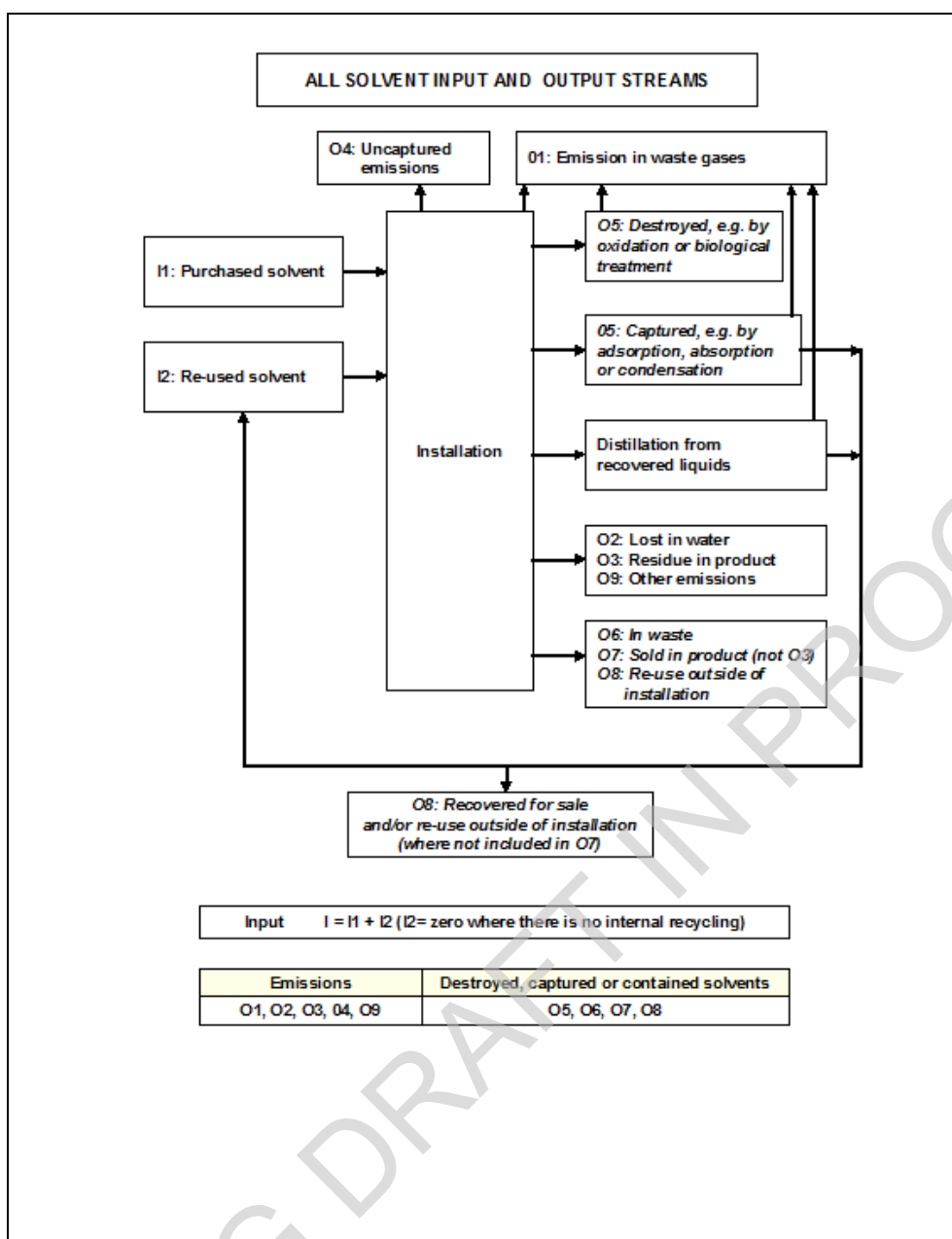
The outputs of organic solvents in the waste gas and as fugitive emissions are more difficult to determine than other emissions, such as water. Emissions are determined by a materials balance, referred to as a solvent balance. A solvent management plan is a tool using a mass balance. Annex VII(7) to the IED provides guidance on what is required in a solvent management plan. It includes the principles to be applied and a framework for a mass balance. A solvent management plan (a mass balance) is used to determine particular requirements, such as:

- verification of compliance with a reduction scheme with a total emission limit value expressed, e.g. in solvent emissions per unit production, or other units (see Annex 0);
- determination of fugitive emissions.

Figure 17.5 shows all of the usual input and output options for solvents.

The five most common cases (illustrated in Annex 21.5) are:

- no end-of-pipe abatement without internal solvent reuse;
- no end-of-pipe abatement with internal solvent reuse;
- solvent recovery and reuse (internally or externally);
- when destructive end-of-pipe abatement is used and the fugitive emissions (e.g. cleaning agents) are easily determined directly;
- end-of-pipe abatement is used and the fugitive emissions are not easily determined.



**Figure 17.5: All solvent inputs and outputs (using definitions from the IED)**

The total emissions  $E = O1 + \text{fugitive emissions}$ .

The fugitive emissions ( $F$ ) can be calculated as:

$$F = I1 - O1 - O5 - O6 - O7 - O8$$

(O7 is unlikely to apply to industries considered in this document)

or  $F = O2 + O3 + O4 + O9$

$F$  can be determined by the direct measurement of the inputs ( $I$ ) and outputs ( $O$ ), see Section 17.3.2, below.

Deriving a mass balance usually involves a mix of direct measurement and estimation that will be derived for a specific situation (see Annexes 0, 21.4 and 21.6). A technique used in several industries (e.g. for the application in vehicle manufacturing industries, see Annex 21.6) is based on such as using the capture and destruction efficiency of the waste gas system using the following steps:



- measure the amount of solvent input ( $I = I1 + I2$ );
- measure the amount of emission in water and losses as waste, etc. ( $\text{Losses} = O2, O3, O6, O7, O8, O9$ );
- measure or calculate the removal efficiency of the abatement technique;
- estimate the amount of solvent sent to abatement ( $I - \text{Losses}$ );
- multiply the amount of solvent by the percentage efficiency of the abatement = waste gas emissions  $O1$ ;
- fugitive emissions (as above):  $F = I1 - O1 - O5 - O6 - O7 - O8$  or  $F = O2 + O3 + O4 + O9$ .

Note: it is not necessary to calculate  $O1$  to calculate fugitive emissions:  $O1$  is needed when the total emissions are calculated (such as to comply with a total emission limit value or where a reduction scheme is used, see Annex 0).

Solvent balances whose function is to prove compliance with regulations or environmental permits are normally drawn up yearly. However, the balances may be prepared more frequently, e.g. monthly or quarterly, for the following reasons:

- Initially, operators will need to apply resources to set up a proper system of data collection and to draw up and check the solvent balances, e.g. one or two man working days per month will be required in large companies. Once a system has been established and key measurements have been identified, they could be easily monitored (see Section).
- Frequent solvent balances can be simpler than the annual balances. For instance, they can be put onto a spreadsheet and/or key indicators can be derived for regular checking, such as changes in stock that can be derived from administrative sources rather than by actual physical stocktaking.
- Making solvent balances is not always easy. The company needs to go along a learning curve. Solvent balances need to be made a number of times before they can be expected to be correct.
- Frequent balances show trends giving an early warning if problems arise. Balancing will discover where emission limits are likely to be exceeded so that it is possible to correct the situation in time and still be in compliance when the solvent balance for the whole year is made.

In order to have an extra check on the correctness of the frequent balances, the annual balance should not be the mere sum of all these balances but it should, as far as possible, be made separately from original data. This annual balance can then be compared to the sum of the frequent balances to find any discrepancies.

#### **Achieved environmental benefits**

Solvent balances are essential to estimate fugitive emissions and therefore control them. Frequent balances indicate any irregular situation, reduce environmental risks and enable the reduction of solvent emissions.

#### **Cross-media effects**

None.

#### **Operational data**

Emission figures should be comparable and it is important that throughout one industry the same definitions are applied, especially what is classed as 'solvent' for the purposes of the mass balance. It is important to note that the IED not only defines a VOC by vapour pressure at standard conditions, but also includes any compound having a corresponding volatility under the particular conditions of use.

When deriving a mass balance, assumptions will usually be made about the efficient working of any waste gas extraction and treatment system. For example, the space ventilated is the same as the design (i.e. no unrecorded connections), equipment such as fans are operating at design

efficiency, etc. Volumes of airflows can be large (e.g. in some cases, orders of magnitude of  $10^6$  m<sup>3</sup>/h), so errors in these figures can cause large errors in calculating emissions emitted (see Annexes and 21.4).

In order for the assumptions to be valid, the ventilation system must be inspected and maintained in good working order (see Section 17.2.7 ~~and specifically Section~~). Examples of problems encountered are (see Annex 21.4):

- the extraction system was not constructed as designed or has been altered without the drawings being updated;
- automatic pressure controls, valves and dampers not working as designed;
- systems working in the wrong way, i.e. blowing instead of extracting, flow being in the wrong direction, etc.;
- fan motors, drive belts and/or pulleys may have been changed, giving different flowrates.

For the determination of volumetric flow, see the Reference literature below, and Section 17.3.2.

The accuracy of the calculated source figures for a mass balance needs to be determined (see Annexes 0 and 21.4). Where the maximum error in any source has no effect on the objective of the mass balance, no further work is necessary to make the estimate more precise.

### **Applicability**

This technique is applicable to all industries applying solvents and is used to calculate fugitive emissions. It is also to demonstrate compliance with the IED where the reduction scheme is used.

Solvent balances may be inaccurate in complex situations, with large deviations where abatement techniques are used (see Operational data, above).

Many countries and industrial organisations have guidance on how to carry out a mass balance and construct a solvent management plan. One includes a free spreadsheet to assist with the mass balance (in English).

### **Economics**

Cost reduction by optimisation of solvent use.

### **Driving force for implementation**

Solvents Emissions Directive. All installations are required to determine either the total emissions or the fugitive emissions separately.

### **Example plants**

Widely used.

### **Reference literature**

[4, Intergraf and EGF, 1999] [38, TWG, 2004] [90, ETBPP, et al., 2004] [113, EIPPCB, 2003] [78, TWG, 2006] [135, ADEME, 2004].

## **17.3.2 Implementation of solvent tracking system**

*TWG please provide more information*

### **Description**

The solvent tracking system controls both the used and unused quantities of solvents returned to storage from the application zone.

**Technical description**

The factor II (quantity solvents / solvent mixtures purchased) is used in the mass balance exercise. There is difficulty in practice in establishing the volume of paint purchased to be used over a reference period, coming from the difficulty of having a perfect inventory in a business where thousands of drums are used, sometimes stored back and reused, and where hundreds of different paint references are a normal situation.

**Achieved environmental benefits**

Enabling better control of fugitive emissions by more accurate establishment of solvent mass balance and therefore fugitive emissions.

**Environmental performance and operational information****Cross-media effects**

None identified.

**Technical considerations relevant to applicability****Economics****Driving force for implementation****Example plants****Reference literature**

[177, ECCA, 2017]

**17.3.3 Full identification, characterisation and quantification of the relevant emission sources**

*TWG please provide more information*

**Description**

This includes:

- identification and listing of emissions sources, i.e. WGT system, each fugitive emissions source;
- substantiated quantification of each emission source's contribution and the methodology used: measurement, calculation using emission factors, estimation based on operational parameters, etc.;
- regular update of emissions data.

**Technical description****Achieved environmental benefits****Environmental performance and operational information****Cross-media effects****Technical considerations relevant to applicability****Economics****Driving force for implementation****Example plants**

Renault, Douai.

**Reference literature**

[181,COM, 2017]

**17.3.4 Monitoring of changes that influence normal operation**

*TWG please provide more information*

**Description**

Any change that could influence the accuracy of the solvent management system is recorded, such as:

- malfunctions of the waste gas treatment: date and period of time;
- changes that may influence air/gas flow rates, e.g. replacement of fans, drive pulleys, motors; the date and type of change are recorded, e.g. replacement to original specification, refurbished, upgraded.

**Technical description**

**Achieved environmental benefits**

Improves the accuracy of solvent mass balance calculations

**Environmental performance and operational information**

**Cross-media effects**

None

**Technical considerations relevant to applicability**

**Economics**

Involvement of personnel

**Driving force for implementation**

**Example plants**

**Reference literature**

**Direct measurement of VOC [solvents and] emissions to air**

*Important. Combined with redrafting of SMB sections. Work in progress.*

**Description:**

Determination of VOC releases by direct measurements

Section 17.3.1, above, says that some inputs (I) and/or outputs (O), as shown in Figure 17.5 may be measured directly. Examples are given in Annex O.

Direct measurement can simply be the measuring by volume or by weight of solvent or materials containing solvent. In some cases, e.g. some cleaning operations, the solvent issued for use is all evaporated and lost as fugitive emissions. In such cases, the volume or weight issued is the amount emitted to air. In other cases, such as where solvent is retained in waste cleaning materials and residues, the weight of solvent in the residues can be determined and subtracted from the solvent issued.

Direct emissions of waste gases may be measured continuously or discontinuously by various types of detection equipment, for parameters such as TOC, CO, dust (particulates), NO<sub>x</sub>. Equally important are the determination of flow and velocity, and understanding and estimating

the uncertainties in the measurement. More information on these techniques can be found in the MON BREF [113, EIPPCB, 2003].

**Achieved environmental benefits:** No data submitted.

**Cross-media effects:** None.

**Operational data:** No data submitted.

**Applicability:** Widely used.

**Economics:** No data submitted.

**Driving force for implementation:** The IED requires all installations to determine fugitive emissions or the fugitive emissions separately.

**Example plants:** No data submitted.

### 17.3.5 Monitoring of emissions to air in waste gases

#### Description

Regular monitoring of emissions to air in waste gases.

#### Technical description

Monitoring of the relevant parameters can be accomplished by online measurements (which facilitate rapid intervention and control) or analytical results derived from air samples. Parameters to be monitored and the frequency of monitoring depend on the characteristics of the type of processes and material used and the abatement techniques applied within the STS plant. See the sector-specific sections on emissions. The monitoring of VOC emissions in waste gases contributes also at the elaboration of the solvent mass balance (determination of emission parameters O1 and O5).

#### Achieved environmental benefits

Control of emissions to air in waste gases, maintenance of proper operation of waste gas treatment equipment and detection of unplanned releases. In addition contribution to the accuracy of the solvent mass balance figures.

#### Environmental performance and operational data

This information (where available) is detailed later in this document for each type of activity in the dedicated chapters (Chapters 2 to 15).

#### Cross-media effects

Some equipment, ancillary materials and energy are required for carrying out monitoring.

#### Technical considerations related to applicability

Generally applicable to all STS plants where there are channelled emissions to air.

#### Economics

The costs associated with monitoring the waste gas relate to personnel and equipment used for sampling and measurement.

#### Driving force for implementation

Legislation on air pollution.

#### Example plants

See examples in Chapters 2 to 15.

### Reference literature

The reference Document on Monitoring [113, EIPPCB, 2003] lists relevant CEN, standards (Comitee European de Normalisation), which are considered most robust, followed by the International Standardisation Organisation (ISO) [113, EIPPCB, 2003]. If the substance cannot be monitored using standards covered by the above then other accredited methods can be used, such the following:

- American Society for Testing and Materials (ASTM);
- Association Française de Normalisation (AFNOR);
- British Standards Institution (BSI);
- Deutsches Institute für Normung (DIN);
- United States Environmental Protection Agency (US EPA);
- Verein Deustcher Ingenieure (VDI);
- other accredited national standards.

If the substance cannot be monitored using standards covered by the above then the following occupational methods may be developed, following the requirements of ISO 17025, for stack emission monitoring:

- Method for the Determination of Hazardous Substances (MDHS) series published by the Health and Safety Executive (HSE);
- National Institute of Occupational Safety and Health (NIOSH); and
- Occupational Safety and Health Administration (OSHA).

National guidance also exists on monitoring certain gases and sampling procedures, e.g. [71, UK DEFRA and notes, 2003] [97, TWG, 2006].

The Guidance document for the European Pollutant Release and Transfer Register (E-PRTR, based on Regulation EC 166/2006) lists internationally recognised measuring methods for air and water pollutants:

<http://ec.europa.eu/environment/industry/stationary/eper/implementation.htm>

### 17.3.6 Monitoring of emissions to water

#### Description

Regular monitoring of emissions to water.

#### Technical description

Monitoring of the relevant parameters can be accomplished by online measurements (that facilitate rapid intervention and control of the WWTP) or analytical results derived from waste water samples. Parameters to be monitored and the frequency of monitoring depend on the activities which are connected to the WWTP and to the destination of the treated effluent (direct discharge or to further treatment in an industrial WWTP or a municipal WWTP).

Common parameters monitored are found in the relevant sector sections on emissions, and include:

TSS, COD, TOC, Zn, Ni, Cr<sub>total</sub>, Cr(VI), Phenol index, AOX, fluoride and phosphates as P.

The monitoring of emissions is carried out in accordance with EN standards or, if EN standards are not available, ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality.

**Achieved environmental benefits**

Monitoring the waste water of a waste treatment plant helps to maintain the proper operation of the waste treatment plant, detect accidental releases and thus helps to prevent any possible adverse environmental effects by discharge of waste waters.

**Environmental performance and operational information**

This information is detailed later in this document for each type of waste treatment in the dedicated chapters (Chapters 3 to 5).

**Cross-media effects**

Some equipment, ancillary materials and energy are required for carrying out monitoring. The COD measurement relies on the use of very toxic compounds (i.e. mercury and chromate).

**Technical considerations relevant to applicability**

Generally applicable to all waste treatment plants where there are emissions to water.

**Economics**

The costs associated with monitoring the effluent waste water of a waste treatment plant relate to personnel and equipment used for sampling and measurement.

**Driving force for implementation**

Legislation on water pollution.

**Example plants**

See the relevant sector sections for emission to water.

**Reference literature**

[23, COM 2006 ] [ 31, COM 2016 ]

**Water**

*Agreed at KOM not to address these issues in detail*

**Preventing hazardous atmospheres in sewers**

*ESVOC: Delete*

**Monitoring of BOD and COD and biodegradability**

*This technique is described fully in the CWW BREF*

**Monitoring and controlling aquatic toxicity**

*This technique is described fully in the CWW BREF*

## 17.4 Water management

More information on process descriptions meant for water management can be found in the STM BREF [59, EIPPCB, 2005].

### 17.4.1 Water use and waste water minimisation

#### 17.4.1.1 Water management plan

##### Description

A water management plan includes:

- flow diagrams and a water mass balance;
- establishment of water efficiency objectives;
- implementation of water optimisation techniques.(e.g. control of water usage, recycling, detection and repair of leaks).

Water audits are carried out at least annually to increase the reliability of controls and to ensure the objectives of the water management plan are met.

##### Technical description

##### Achieved environmental benefits

Reduction in water consumed and waste water discharged.

##### Environmental performance and operational information

##### Cross-media effects

None reported.

##### Technical considerations relevant to applicability

The scope (e.g. level of detail) and nature of the evaluation will generally be related to the nature, scale and complexity of the installation and raw materials used, and the range of environmental impacts it may have.

##### Economics

Staff time.

Cost of any additional metering required.

##### Driving force for implementation

Cost reduction depending on pricing of water and availability.

##### Example plants

Crown Bevcan, Custines, FR.

##### Reference literature

[155. TWG, 2016]

#### 17.4.1.2 Optimisation of water usage Control of water usage

##### Description

Water usage and discharge is optimised by managing the flow and water quality, e.g. of rinse and process waters. This may also assist the reuse and recycling of water.

##### Technical description



Water usage can be optimised to meet quality requirements such as by benchmarking, calculation, chemical or physico-chemical analysis (which can be online or manually). The water flow is then controlled by an authorised person using a variety of techniques such as using locking flow valves, or monitoring key parameters, e.g. metering volumes temporarily or permanently. For example, for rinsing, the conductivity in the last water rinsing step is related to the maximum allowed load of contaminants which may influence further surface treatment processes. Monitoring the discharge from the rinses using conductivity measurements can reduce the amount of water used, because it helps to control the amount of make-up water required.

Determining the quality of various process waters provides information for the reuse and recycling of waters, either directly or after relevant treatment.

#### **Achieved environmental benefit**

Water consumption and waste related to rinsing water will be reduced and the lifetime of further chemical treatment baths will be improved.

Waste water volumes will be reduced.

#### **Cross-media effects**

Reducing water usage could result in higher emission levels, such as BOD and COD emissions and potential stress on WWTP.

#### **Operational data**

The conductivity equipment and other online monitoring equipment need to be robust in handling and maintenance.

On coil coating, the allowed conductivity for the last water rinsing step depends on the further process, but is generally between 10  $\mu\text{S}/\text{cm}$  and 100  $\mu\text{S}/\text{cm}$  (20 °C). Measurement must be temperature compensated.

#### **Technical considerations relevant to applicability**

Applicable where water-based techniques are used, e.g. water-based cleaning, treatment baths, coatings or wet scrubbers are used.

This technique is widely used in the coil coating industry and vehicle coating industry.

#### **Economics**

Low investment costs are involved for the conductivity equipment. Savings are achieved because there is a reduction of water consumption and waste generation.

#### **Driving force for implementation**

Economics and overall process stability.

#### **Example plants**

No data submitted.

#### **Reference literature**

[22, ECCA, 2004][23, COM 2006][31, COM 2016]

### **17.4.1.3 Reverse cascade rinsing**

Multiple stage rinsing in which the water flows in the opposite direction to the workpieces/substrate. It allows a high rinsing rate with a low water consumption. This technique and associated techniques required to achieve this are described fully in the STM BREF.

**Technical considerations relevant to applicability**

Applicable where water-based techniques are used, e.g. cleaning and/or treatment baths, and /or coatings.

**17.4.1.4 Reuse/recycling of water**

**Description**

Spent rinse-water can be regenerated using such as ion exchange or filtration. Closed loop systems can be used in systems such as such as in cooling towers (~~closed systems~~) or heat exchangers reduces the amount of water used on the line.

~~This can lead to~~ Savings in water consumption are achieved and will reduce the amount of waste water to be treated, reducing the waste water treatment costs for capital investment, energy usage and chemicals. However, the cost of regeneration equipment and running costs needs to be considered. This technique and associated techniques required to achieve this are described fully in the STM BREF.

**Technical considerations relevant to applicability**

Generally applicable

**Reuse of water within the plant**

*This technique is combined with Section 17.4.1.3*

**17.4.1.5 Recycling of wet scrubber/venturi scrubber water**

*TWG please provide more information. Can this be applied more widely to other wet scrubber systems?*

**Description**

Effluent from venturi scrubbers is treated on a continuous basis. Paint particles are coagulated and flocculated and the resulting paint sludge is removed continuously, allowing the water to be recycled.

**Technical description**

Due to the large flow rate, the coagulation of paint sludge from venturi scrubber effluents is frequently performed on a continuous basis. Paint particles are coagulated using organic polymers followed by flocculation using iron salts and milk of lime (lime water) or bentonite. The coagulated paint sludge is removed continuously by sedimentation or flotation, allowing the water to be recycled in the scrubber system. The thin sludge is usually dewatered using decanter centrifuges and the thickened sludge disposed of as waste.

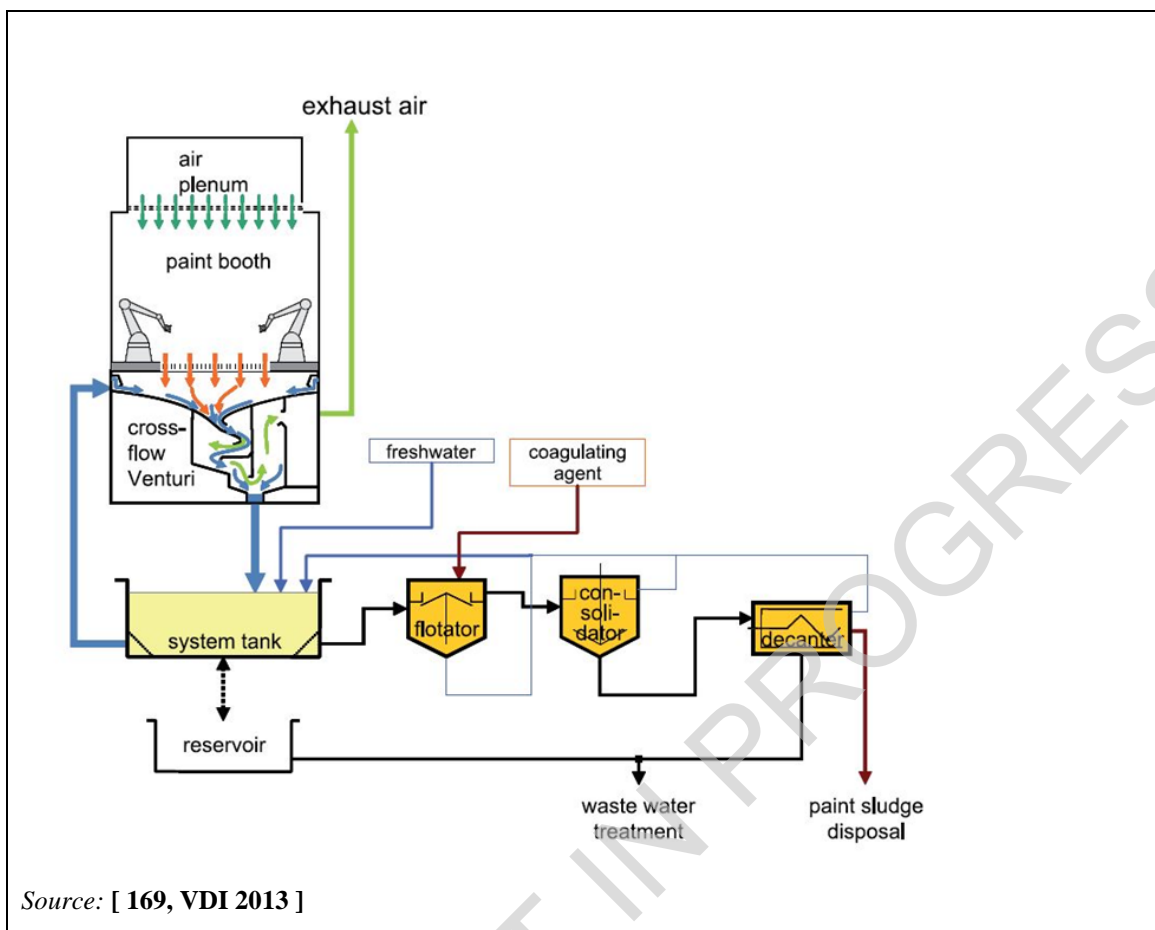


Figure 17.6: Simplified process flow chart of paint booth water recycling with paint sludge coagulation

#### Achieved environmental benefits

Significant reduction in water usage.

Waste is reduced by thickening the sludge.

#### Environmental performance and operational information

##### Cross-media effects

#### Technical considerations relevant to applicability

Applicable to wet/venturi scrubber systems for paint overspray capture.

#### Economics

#### Driving force for implementation

Cost savings in water usage.

#### Example plants

Widely used. In particular, used in the vehicle coating industry and the coating of trains.

#### Reference literature

[ 169, VDI 2013 ]

#### **17.4.1.6 Regeneration by ion exchange**

Ion exchange is the removal of undesired or hazardous ionic constituents of waste water and their replacement by ions  $H^+$  and  $OH^-$  from an ion exchange resin. This technique and associated techniques required to achieve this are described fully in the STM BREF.

##### **Technical considerations relevant to applicability**

Applicable to ionic contaminants in water streams.

#### **17.4.1.7 Magnetic separator**

*TWG please provide more information*

##### **Description**

Magnetic material is extracted from water using a magnetic force.

##### **Technical description**

##### **Achieved environmental benefits**

##### **Environmental performance and operational information**

##### **Cross-media effects**

##### **Technical considerations relevant to applicability**

Applicable to magnetic particles.

##### **Economics**

##### **Driving force for implementation**

##### **Example plants**

##### **Reference literature**

No information provided.

#### **17.4.1.8 Filtration (Ultra and nanofiltration and reverse osmosis)**

See Section 17.11.8

## 17.5 Energy management

*Most of the following techniques are described fully in the ENE BREF*

### 17.5.1 Energy efficiency plan

#### Description

An energy efficiency plan entails defining and calculating the specific energy consumption of the activity, setting key performance indicators on an annual basis (e.g. MWh/tonne of product) and planning the periodic improvement targets and related actions

The energy efficiency plan gathers a set of organisational and technical measures aiming at using energy efficiently. It is part of the environmental management system (EMS).

#### Technical description

Extensive information about energy efficiency can be found in [153, BREF ENE]. Some techniques applicable to increase the energy efficiency of STS activities are as follows:

- a. Appraising the costs and benefits of different energy options.
- b. Monitoring of energy flows (consumption and generation by source) and the targeting of areas for reductions.
- c. Defining and calculating the specific energy consumption of the activity (or activities), and setting key performance indicators on an annual basis (e.g. MWh/tonne of product or per tonne of solvent used). For example, based on the primary energy consumption for the products or raw material inputs which most closely match the main purpose or production capacity of the plant.
- d. Carrying out an energy survey to identify the opportunities for further energy savings.
- e. Using combined heat and power (CHP).
- f. Applying operating, maintenance and housekeeping measures to the most relevant energy consumption plants, such as:
  - air conditioning, process refrigeration and cooling systems (leaks, seals, temperature control, evaporator/condenser maintenance);
  - operation of motors and drives (e.g. high-efficiency motors);
  - compressed gas systems (leaks, procedures for use);
  - steam distribution systems (leaks, traps, insulation);
  - room heating and hot water systems;
  - lubrication to avoid high friction losses (e.g. mist lubrication);
  - boiler maintenance, e.g. optimising excess air;
  - other maintenance relevant to the activities within the plant;
  - reviewing equipment requirements on a regular basis;

### 17.5.2 Energy balance record

#### Description

An energy balance record provides a breakdown of the energy consumption and generation (including exportation) by the type of source (e.g. electricity, gas, conventional liquid fuels). This includes:

- (i) defining the energy boundary of the activity;
- (ii) information on energy consumption in terms of delivered energy;
- (iii) information on energy exported from the plant;
- (iv) energy flow information (e.g. Sankey diagrams or energy balances) showing how the energy is used throughout the process.

The energy balance record is adapted to the specificities of the plant in terms of process(es) carried out, materials, etc.

Monitoring and measurement are an essential part of checking in a 'plan-do-check-act' system, such as in energy management (see also ENE BREF). It is also a part of the effective control of processes.

**Reference literature**

[ENE BREF]

**17.5.3 Thermal insulation of tanks and vats containing heated liquids**

**Description**

This may be achieved by:

- using double skinned tanks;
- using pre-insulated tanks;
- applying insulation to combustion equipment, steam and hot water pipes

**Technical considerations relevant to applicability**

Generally applicable

**17.5.4 CCHP (combined cooling, heat and power)**

**Description**

A cogeneration system with an absorption chiller that uses low grade heat to produce chilled water. Also called trigeneration.

See the ENE BREF for more information.

**Technical considerations relevant to applicability**

Generally applicable

**17.5.5 Recovery of heat from off-gases**

**Description**

Energy recovery from off-gas thermal treatment processes and hot air streams (e.g. from dryers, cooling zones)

See the ENE BREF for more information on heat recovery in general, as well as from compressed air systems, drying processes.

**Technical considerations relevant to applicability**

Generally applicable

**17.5.6 Oxidiser heat saving during shut-down periods (bottle up heat saving on oxidiser)**

*TWG please provide additional information*

**Description**

Oxidiser heat is kept inside chambers during production shutdown periods (e.g. weekends)

**Technical considerations relevant to applicability**

Generally applicable

### 17.5.7 Flow adjustment of process air and off-gases

#### Description

Adjust the flow of process air and off-gases according to the need. Reduce air ventilation during idle operation or maintenance. See Section .

#### Technical considerations relevant to applicability

Generally applicable

### 17.5.8 Spray booth off-gas recirculation

#### Description

Capture and recirculate off-gas from the spray booth in combination with efficient paint overspray separation. Energy consumption is less than in the case of fresh air use.

#### Technical considerations relevant to applicability

Only applicable to spray coating sectors

### 17.5.9 Temperature and humidity optimisation of the process air

#### Description

Maintain process air conditions (humidity, temperature) at the desired ranges.

#### Technical considerations relevant to applicability

Generally applicable *TWG, please comment*

### 17.5.10 Optimisation of energy consumption for the warm air circulation required for curing,

#### Description

Air is blown into a single part of the booth and distributed using an air turbulator which turns the laminar air flow into the desired turbulent flow. In general, ventilation uses slightly less energy.

#### Technical considerations relevant to applicability

Only applicable to spray coating sectors

### 17.5.11 Proper dimensioning of the waste gas extraction system and of the abatement system

#### Description

The dimensioning of the extraction system and the selection of the abatement technique take into account:

- the emissions pattern (continuous/discontinuous);
- the energy content of off-gases and the effect of energy consumption below autothermal conditions;
- the costs and benefits of treating emissions with low VOC concentrations, in terms of energy consumption.

#### Technical considerations relevant to applicability

Generally applicable

### **17.5.12 Optimisation of the waste gas extraction and abatement processes**

This optimisation is based on:

- the amount of air to be extracted;
- the type and likely level of solvents;
- the type of treatment and its costs and benefits and cross-media effects (e.g. material, energy consumption);
- the number of hours per year in operation.

#### **Optimisation of electrical power supply**

*This technique is described fully in the STM BREF*

#### **Optimising electricity demand**

*This technique is described fully in the STM BREF*

#### **Energy efficient equipment**

*These techniques are described fully in the STM BREF*

WORKING DRAFT IN PROGRESS



## 17.6 Raw material management (including substitution)

### 17.6.1 Systematic evaluation to reduce environmental impact of used materials

*To be updated – work in progress.*

#### ~~Quality assurance of paints and solvents~~

*Combined with previous Sections 20.7.2.9 and 20.10*

#### **Description**

Systematic evaluation and reduction of adverse environmental impacts to air and water by identifying and seeking to replace substances by others with lower environmental impact (including lower toxicological impact).

See also Section 17.6.2

~~Paints and solvents are usually approved by competent experts (in-house or external) before use in paintshops. This approval procedure consists of thorough quality testing and includes verification that no substitute materials with higher toxicological or environmental impacts are used. Quality testing and verification procedures must be designed to specifically take into account environmental, health and safety risks of products.~~

#### **Technical description**

*Added from previous 20.10*

Surface treatment using solvents uses a wide range of chemicals in a wide range of processes. ~~Annex IV, point 2, to the IPPC IED Directive requires the use of less hazardous substances to be considered.~~ The IED Directive lists one of the criteria for determining BAT to be the use of less hazardous substances (Annex III (2)).

The use of less harmful substances (substitution) can be achieved in one of three ways:

1. Direct replacement of one substance by a less hazardous one. This is usually limited to simpler systems, for example, replacement of low flashpoint cleaners by high flashpoint ones (see Section 17.9.6).
2. Replacement by different process chemistries or techniques using less hazardous substances. This is used where there is no direct replacement. Different coating process chemistries give treatments with different properties, even for the same materials. For examples, see Table 17.4. This is the principle route for replacing harmful substances in this sector, and is dealt with in the appropriate activity and industry chapters.
3. Eliminating the surface treatment process in the installation and using, for example, pre-coated materials in production (e.g. for producing white goods or construction panels). This type of substitution may be shown to be environmentally beneficial (e.g. in life cycle studies) and may be considered by an operator to achieve various objectives including reducing VOC emissions. However, the IPPC Directive refers to the installation and the activities used. This type of substitution (in effect, cessation of the process within the installation) is therefore not a technique likely to be considered in determining BAT and is not discussed further in this reference document.

Table 17.4: Examples of solvent substitutes used in the STS sector

<b>Low solvent coatings</b>	High solids
	Two-component (chemically inter-reacting)
	Water-based
	Powder slurry
<b>Solvent-free coatings</b>	Hot melts
	Powder coating
	Powder polyester coating
	Radiation curable coating

Substitution not only applies to solvents used in cleaning substrates, equipment and facilities, but also to other components used in the processes, such as pigments, preservatives, binders, surface active agents, etc.

Some substances are covered by other European and/or national legislation or guidance, and the risk phrases supplied with manufacturers' data can be a useful start to identifying materials with significant health and environmental hazards. The following are possible hazard attributes for substances used in this sector:

#### **Classification as SVHC (replaces old Section 17.6.2) ~~adverse physiological effects~~**

A substance may be proposed as an SVHC if it meets one or more of the following criteria given in article 57 of the REACH Regulation:

- it is carcinogenic;
- it is mutagenic;
- it is toxic for reproduction;
- it is persistent, bioaccumulative and toxic according to the criteria set out in Annex XIII to the REACH Regulation[5] (PBT substances);
- there is 'scientific evidence of probable serious effects to human health or the environment which give rise to an equivalent level of concern'; such substances are identified on a case-by-case basis.

#### **Current situation for Cr(VI)**

*Conversion coatings in coil coating have traditionally used Cr(VI) (chromate) rinses widely, after the pretreatment and/or surface preparation (e.g. brushing) and before painting. However, under the REACH Regulation [REACH 2006], the Cr(VI) compounds used in such rinses have a 'sunset date' of 21 September 2017, and as they are listed as Annex XIV substances will require specific authorisation for each use.*

*At the time of this draft, applications for authorisations have been registered, but one has been approved. BAT conclusions have been based on the possibility of likelihood of continued use for in the aerospace industries and possibly for certain coil-coated products.*

*Paint pigments have contained toxic metals such as cadmium, hexavalent chromium, nickel and lead for the colour of their compounds and for corrosion resistance. However, their use is now strictly limited by regulations to activities which are not in the scope of this document, see Section 1.2.3. There is now a REACH sunset date of Jan 22 2019 for various CrVI substances potentially used in paint pigments, some having slight solubility in water. The due date for applications for authorisation is July 22 2017. There are currently applications from about 10 manufacturers for CAS number 7789-06-2 (strontium chromate) for use in aerospace coatings and one for CAS 11103-86-9 for unspecified use in primers, sealers and coatings.*

~~Other substances and/or different techniques can be used to replace substances or preparations, which, because of their contents of VOCs are classified as carcinogens,~~

mutagens or toxic to reproduction under Directive 67/548/EEC, and are assigned or carry the risk phrases R45, R46, R49 R60, R61.

- **physico-chemical effects:** the following risk phrases are not regarded as measures of environmental impact (except where subject to [134, EC, 2003]): explosive, oxidising, extremely flammable, highly flammable and flammable;
- **photochemical oxidant formation (ozone-formation potential, OFP:** see Chapter 1; and Section 17.6.2
- **stratospheric ozone depletion potential (ODP)** (see Section 17.6.2.2);
- ~~**global warming potential (GWP);** the GWP of a substance is a measure of the extra amount of heat that is trapped in the atmosphere when one kilogram of the substance is released instantaneously into it, relative to the case when 1kg carbon dioxide is released~~
- **ecotoxic effects:** these are described by the labelling accompanying the raw materials set out in the Classification, Labelling and Packing Regulation (1272/2008) Marketing and Use Directive as amended [51, COM, 1976]; in this sector, aquatic ecotoxicity toxicity as defined by the risk phrase R50/53 relevant hazardous statements. may be one of the most relevant where there is a risk of contact with water, such as where solvent based systems that are replaced with predominantly water based systems. These may require the addition of biocides, or the raw materials may have intrinsic aquatic toxicity, or there is a risk of spillage, see Section 0
- **odour:** many VOCs have an odour. In certain circumstances emissions of VOCs can give rise to localised odour nuisance problems (see Section 17.13). There is no EU-wide measure for odour, although methods exist in various MS
- ~~**damage to material:** information can be found on corrosiveness or other properties of VOCs which might lead to the damage of materials. However, such damage is unlikely to occur at any distance from the point of discharge, due to dilution through dispersion. For these reasons such VOCs are not considered hazardous, although POCP (see Section 17.6.2.2) takes account of ozone formation that may lead to ozone attack on certain materials.~~

### Achieved environmental benefits

Reduction in the use of harmful substances, e.g. solvents, and the amounts subsequently entering the environment, either planned (e.g. in waste gases) or unplanned (e.g. fugitive emissions, leaks, accidents in handling, etc.).

There may be other improvements in environmental performance, such as the saving of energy in the process or in waste gas treatment, the use of less raw material in the process or waste water treatment, less water usage, the production of less waste classified as hazardous, and lower emissions of noise or dust, etc.

### Cross-media effects

These effects depend on the individual alternative techniques. Some may have effects such as increased energy usage, increased waste generation or increased water or raw material consumption. Some alternative materials may increase health and safety risks, have a higher photochemical reactivity (see Section 17.6.2) or increase other environmental risks. One simple approach for assessing if the health risks are increased is to use the Vapour Hazard Ratio (see Applicability, below). Further information can be found in the ECM REF.

### Operational data

*To be updated.*

### Applicability

~~In large companies where paint application is a major quality topic.~~

Substitution decisions have to be made on a case-by-case basis, and the substitution must adequately achieve the final performance characteristics required (i.e. have suitable functionality). In all cases, it is essential to discuss the changes with the customer in advance of making the substitution. It is good practice not make changes without full knowledge of the final performance characteristics required. Because of the risk of failure to meet these

characteristics, it is advisable for both operator and customer to monitor quality and performance to, and exchange information on, the required specification.

In some processes using single substances, substitution may not be possible, e.g. it is not currently possible to replace toluene in publication gravure printing.

Given the wide range of chemicals used in this sector, it is doubtful that all chemicals with potential to cause harm to the environment can be suitably replaced. Some processes may depend on harmful substances where there is no suitable substitute or the cross-media effects (see above) outweigh the benefits.

To assist with comparing possible alternative substances, ratios may be derived. For example, for physiological effects, the Vapour Hazard Ratio (VHR) compares the tendency of a product to evaporate with its OEL (Occupational Exposure Limit) as shown below:

$$\text{VHR} = \frac{\text{Equilibrium vapour concentration (at 20 °C)}}{\text{OEL}}$$

As a consequence:

- for products with a similar OEL, choose the product of lowest volatility;
- for products with a similar volatility, choose the product with a higher OEL.

Where the data are less easy to interpret, the calculation may have to be made.

Other factors, such as toxicity and ecotoxicity can be judged on a simple basis, such as using a substance with a lower risk phrase. Alternatively, other metrics (such as ozone forming reactivity, see Section 17.6.2, can be used. In some cases, such as with OFP, a ratio analogous to VHR could be developed.

### **Economics**

~~In house material testing and approval is very cost intensive, and is only installed for accomplishing high paint quality.~~

Substitutes may be more cost effective but this needs to be determined on a case-by-case basis. They may enable the installation to meet more than one set of legislative requirements (see Driving force for implementation, below). Savings may be found in, for example:

- decreased energy, water and raw material usage;
- decreased waste gas and waste water treatment;
- increased health and safety compliance in the workplace;
- improved quality and reliability of the process.

### **Driving force for implementation**

Health and safety of employees is a major driver for using less harmful substances. (Note: care should be taken with replacing for occupational health reasons to ensure the replacements are in fact less harmful according to all the evidence available).

Customer (health) quality demands.

Other environmental legislative drivers are, e.g. ~~the Solvent Emissions Directive, and a~~ PARCOM recommendation for materials discharged to water. REACH. Product and wastes legislation ELV, WEEE, etc.

Reducing regulation: In some cases, the solvent reduction achieved can result in lowering the solvent use below the threshold levels considered for ~~IPPC-IED~~ or other regulation.

### **Example plants**

See Sections 2.4.3, 0, 0, 3.4.3.1, 3.4.4.1, 4.4.4.1, 0, 6.4.2, 10.4.1, 3.4.2.6 and 14.4.2.  
All automotive OEMs

#### Reference literature

[59, EIPPCB, 2005], [42, Envirowise, 2003, 50, COM, 2005, 73, COM, 1999, 78, TWG, 2005, 116, ESIG, 2005] [38, TWG, 2004] [78, TWG, 2005] [52, COM, 2000]

### 17.6.2 Replacement of solvents and other materials with CMR properties (substitution)

#### Description

Article IED requires the replacement as the replacement of CMR substances as far as possible by less harmful substances or mixtures within the shortest possible time.

#### Achieved environmental benefits

No data submitted.

Reduction of emissions of CMR substances

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

Substitution has been applied successfully in the printing industry. For replacement of solvents: Installations have replaced solvent-degreasing with non-solvent cleaning, although the solvents replaced may not always be CMR solvents (see Section 17.9.6).

#### Economics

No data submitted.

#### Driving force for implementation

Health and safety in the workplace. REACH.

Article 58 of the IED states that:

'Substances or mixtures which, because of their content of volatile organic compounds classified as carcinogens, mutagens, or toxic to reproduction under Regulation (EC) No 1272/2008, are assigned or need to carry the hazard statements H340, H350, H350i, H360D or H360F, shall be replaced, as far as possible by less harmful substances or mixtures within the shortest possible time.'

#### Example plants

Most paint shops in Germany and analogous activities handling comparable substrates in Europe.

#### Reference literature

[51, COM, 1976, 73, COM, 1999] [78, TWG, 2005]

#### 17.6.2.1 Using solvents with lower ozone-forming potential (OFP)

*Important: Whole section needs updating for latest policy and legislation.*

#### Description

Different VOCs react differently when they are emitted to the air: this is referred to as ozone-forming reactivity or potential. VOC reactivity is not a static function of a compound, but varies with the ambient conditions. Temperature, the amount of sunlight available and the

concentration of  $\text{NO}_x$  as well as other VOC compounds in the air can have an effect on the potential for a particular compound to form ozone. Meteorology also plays an important role. Assigning a reactivity value to VOCs is, therefore, a complicated task.

The most common scales used to compare the reactivity of different VOCs are:

- the photochemical ozone creation potential (POCP) (discussed in the ECM REF);
- the maximum incremental reactivity (MIR), derived for regulation in California, US.

An alternative scale called IDOP – maximum integrated downwind ozone production – has been developed in the UK. IDOP is expressed in ppb ozone per VOC emission rate in tonnes per hour. Only about 100 IDOP values have been calculated for individual substances, and it is recommended that more assessments be conducted before applying IDOP routinely. This is a suitable field for future research (see Concluding Remarks, Section 20.4). As MIR is calculated for Californian climatic conditions, this leaves POCP as the most suitable option to work with currently.

The use of a scale for OFP allows a mixture of VOCs to be summed (see the ECM REF). However, the OFP is usually used in assessing the effect of substances already volatilised (e.g. in spray booths, dryers) and released, such as in modelling. Where the substances are not automatically volatilised (e.g. for some cleaning materials), this may need to be taken into account. The Swan Eco-label uses an effective ozone creation potential,  $\text{POCP}_{(\text{effective})}$  (the POCP multiplied by the relative rate of evaporation). An approximate surrogate is to use vapour pressure multiplied by the POCP (see Annex 21.7).

The impact of a solvent mixture on ozone formation for materials can then be expressed as:

$$\text{POCP}_{(\text{effective})} = \sum_1^n x_1(\text{POCP}_{(\text{effective})1}) + x_2(\text{POCP}_{(\text{effective})2}) + \dots x_n(\text{POCP}_{(\text{effective})n})$$

Where:

$x_1$  is the concentration of substance 1 in the mixture;

$(\text{POCP}_{(\text{effective})1})$  is the effective ozone creation potential (this equals POCP where all the solvent is volatilised in the process).

A similar formula (but using weight volatilised instead of concentration) can be used to compare the effects of the release of different amounts of different solvents released from different formulations.

Figure 17.7 below shows graphically how the formula works when assessing if a substitution proposal achieves an environmental benefit.  $\text{VP}_n$  is the vapour pressure of  $n$  components (as a first approximation; this sum approach assumes no physico-chemical interaction between the different components, which is likely to be a 'worst case' approach).

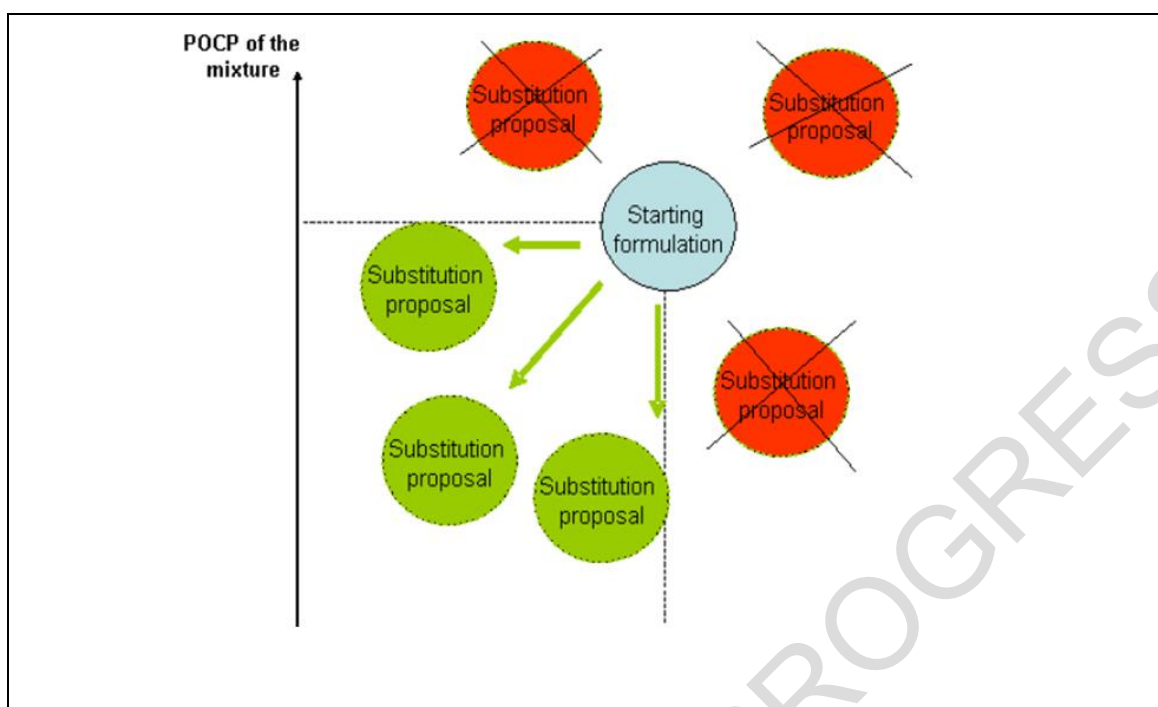


Figure 17.7: Assessment of potential substitutions by POCP

#### Achieved environmental benefits

The direct replacement of high reactivity light aromatic solvents, e.g. toluene, xylene and solvent naphtha (C9 aromatics), with lower reactivity alternatives offers the potential for VOC-related POCP reductions of about 20–40 % (see Applicability, below).

Some aromatic solvents are classified as dangerous for the environment (R51/53; exceptions include toluene, xylenes and ethylbenzenes) so their replacement might be beneficial for the aquatic environment as well, depending on the selected replacement products.

#### Cross-media effects

Chlorinated VOCs tend to have low ozone-forming reactivity, but high stratospheric ozone-depleting potentials as well as toxic effects.

#### Operational data

See Applicability, below.

#### Applicability

While OFP is the scientific reasoning behind the need to reduce emissions of VOCs, the use of OFP is in its early stages and cannot be used to show compliance with existing legislation such as IED (at operator level) and National Emissions Ceilings (at Member State level).

The technique is not applicable in installations where solvent emissions are adequately abated or prevented, such as by waste gas treatment, see Section 17.10.

The VOC reactivity calculations show that, although there is some variation in the relative rankings of individual VOCs, the light aromatic solvents are shown to be the most reactive products in terms of ozone formation by all three scales (and the same was found with other scales that have been tested in the US). In general, replacing light aromatic products in surface treating formulations can result in a significant reduction in the OFP of the final product in spite of the uncertainties associated with POCP (or other reactivity) values. However, it is important to note that although chlorinated VOCs generally have low values in ozone formation scales, they should not be used to replace non-chlorinated VOCs, as they have high ODP values (see Section 17.6.2.2), as well as health and safety impacts.

Complex systems, such as automotive paints (and some types of printing inks), may contain up to about 30 different solvents. This sophisticated mixture of solvents is used to achieve particular specifications, such as colour, drying, durability, etc. Changing these to decrease the overall  $POFP_{total}$  while meeting the quality requirements would require a major investment by the industry (see Economics, below) and could not be achieved by one automotive manufacturer or installation in isolation. However, it may be implemented over a longer time period as a consideration with the ongoing formulation of paints (e.g. through REACH, see Driving force for implementation, below) and is a suitable field for future research (see Concluding Remarks, Section 20.4).

In some processes using solvents with a higher OFP, these solvents cannot be replaced for technical reasons. This can be the case even where there is a single principle solvent used in the processes, such as toluene in publication gravure printing.

OFP can be used (within the limitations described in this section) to guide replacements for other hazards (as described in Section 17.6.2.2) to make sure these replacements decrease (or at least do not increase) the overall OFP. This is important to consider where substitution is used to achieve emission targets. It may be used where other measures cannot achieve the associated emission values or are not technically applicable (such as having unfavourable cross-media effects). It may be most readily used for simple systems, such as guiding replacement for cleaning solvents (see Sections 17.9 and 17.6.2.2) and solvent carriers for wood preservation (see Chapter 18). Where OFP is used, then the POCP figure can be used where the solvent is evaporated and the  $POCP_{effective}$  should be used where evaporation is only partial (e.g. with some cleaning techniques).

### **Economics**

The automotive industry estimates a cost for implementation for automotive paints in the range of EUR 100 million to EUR 3 500 million and a timescale of approximately 10 years. In addition, there are likely to be hidden costs for implementing this type of change in production, where new solvent systems may not have the same characteristics.

### **Driving force for implementation**

Policy and regulations decreasing the formation of ground level ozone (UNECE Gothenburg Protocol and EU National Emissions Ceilings Directive 2001/81/EC), ~~CAFE (Clean Air For Europe)~~, REACH, etc.

Light aromatic solvents have relatively low occupational exposure limits, so from an occupational health point of view, their replacement can be favourable as well.

Ethylbenzene, a component of industrial xylene, is undergoing an EU risk assessment under the Existing Substances Regulation 793/93/EEC. Toxicological tests on ethylbenzene have shown some carcinogenic activity in rats and mice and as a result, the International Agency for Research on Cancer has classified ethylbenzene as a Group 2B carcinogen (possible carcinogen to humans).

### **Example plants**

Applied by local air pollution control authorities in the US, in particular, MIR is used by Californian regulators and industry.

### **Reference literature**

[4, Intergraf and EGF, 1999] [38, TWG, 2004] [96, European Solvents Industry Group, 2005] [50, COM, 2005] Swan Eco-label [www.Svanen.nu] [97, TWG, 2006, 117, Lemoine, 2006, 118, Tempamy and Lemoine, 2006, 120, May, 2006]



### 17.6.2.2 Replacement of halogenated solvents

#### Description

Halogenated solvents can be replaced by less hazardous solvents, e.g. where a powerful solvent action is required for cleaning. Powerful solvents such as ~~n-methyl-2-pyrrolidone~~ and ethanolamine can be used. Where paints are based on halogenated solvents, alternative paint systems can be used (see Section 17.7).

#### Achieved environmental benefits

Reduced hazard of emissions during handling and to air and reduced hazardous waste generation.

#### Cross-media effects

No data submitted.

#### Operational data

Chlorinated hydrocarbons are sometimes used for degreasing surfaces in the production of friction lining, and as the solvent for some coatings for agricultural and construction vehicle coating.

In flexible packaging, halogenated solvents such as methylene chloride were used to remove persistent contamination. However, they have been replaced by non-volatile solvents such as n-methyl-2-pyrrolidone and ethanolamine.

#### Applicability

Applicability depends on the specific technique and its use. Substitution has been applied successfully in the printing industry (through legislation and EU-wide industry agreements), in friction lining manufacturing, and is commonly applied in all industry sectors. Paint systems are available that can replace paints using halogenated solvents.

#### Economics

No data submitted.

#### Driving force for implementation

Health and safety in the workplace. The IED sets an emission limit value of 20 mg/Nm<sup>3</sup> where the mass flow of halogenated VOCs with the hazardous statements H341 or H351 is equal to, or greater than, 100 g/h.

In Germany, the use of halogenated solvents is considered obsolete.

#### Example plants

Halogenated solvents have been replaced on a wide scale (e.g. in Germany)

#### Reference literature

[4, Intergraf and EGF, 1999] [12, UBA Germany, 2002] [38, TWG, 2004] [78, TWG, 2005]

### 17.6.3 Management plan to optimise the use of organic solvent in the process

#### Description

The management plan aims at identifying and implementing actions to optimise the use of solvents (e.g. less paint coats, number of colours, colour batching, optimise spray pulverisation)

#### Technical description

Set up and implement a management plan to optimise the use of organic solvent in the process. The management plan aims at identifying and implementing actions to optimise the use of

solvents. There are various techniques that could be considered e.g. less paint coats, number of colours, colour batching. The management plan for the optimisation of the use of organic solvents is part of the environmental management system (EMS) and the decisions on the techniques to be applied are based on the interaction with other EMS constituents.

### **Environmental performance and operational information:**

#### **Cross-media effects**

#### **Technical considerations relevant to applicability**

#### **Economics**

#### **Driving force for implementation**

#### **Example plants**

#### **Reference literature**

### **17.6.3.1 Batch painting/colour grouping**

*TWG please provide additional information*

#### **Description**

In order to reduce rinsing operations between two different colours of car painting in solvent based paint shops, the production is reorganised between primer and base coat stages.

~~Batch painting, also called colour grouping or block to block painting, means that a series of a specific products is painted in the same colour. This will result in less frequent changes to a different colour.~~

#### **Technical description**

At the end of primer stage, after the oven, the conveyors used to empty the oven at the end of production are also used to store and reschedule cars in order to create small convey of cars with the same colour.

#### **Achieved environmental benefits**

Reduction of rinsing solvent use by reducing the number of rinsing operations between different colours. The benefit is directly linked with the length of pipe between colour tank and painting tool. Less paint residues produced requiring cleaning.

~~VOC reductions through reduced paint line cleaning/purging.~~

#### **Environmental performance and operational information**

Sufficient storage space has to be available for the products as well as an appropriate logistical planning system. It also depends on the number of different colours and their relative abundance in the production programme. For the automotive industry, the average colour group length is between two and six units.

#### **Cross-media effects**

None.

#### **Technical considerations relevant to applicability**

This technique is commonly applied ~~in the automotive industry~~, in the coating of cars, trucks and commercial vehicles and in the coating of metal packaging.

Not applicable in printing processes.

#### **Economics**

Savings in paint, solvents and cleaning/downtime are offset by higher storage capacity costs.

**Driving force for implementation**

No information provided.

**Example plants**

Commonly used in most automotive plants.

**Reference literature:** [13, DFIU and IFARE, 2002] [68, ACEA, 2004] [38, TWG, 2004] [78, TWG, 2005][ACEA 2017]

WORKING DRAFT IN PROGRESS

## 17.7 Coating processes and equipment

### 17.7.1 Pretreatments prior to painting

Water-based pretreatments are applied for three reasons: to remove grease and dirt from previous operations, improve corrosion resistance and to improve adhesion of the subsequent paint layers. The usual pretreatments applied are degreasing, phosphating and chromating. These techniques are described fully in the STM BREF [59, EIPPCB, 2005], together with associated BAT for materials conservation and maintenance, as well as BAT conclusions, and are therefore not discussed in full here. ~~More information can be found in the STM BREF [59, EIPPCB, 2005]. These processes are not applied in the coating of wood and furniture as they are not necessary and they remove oils from the wood.~~

#### **Solvent-based degreasing**

*Combined with section 17.9.4*

##### **Description**

#### **Water-based degreasing**

*Combined with 17.9.6*

##### **Description**

See Section 17.9.6.

#### 17.7.1.1 Phosphating

##### **Description**

Phosphate conversion coatings are used to enhance corrosion resistance and the adhesion of subsequent paint coatings to steel substrates. They typically contain iron, zinc, nickel and manganese. They can be applied by spray, but are currently usually applied by dipping to give a more complete and consistent coating.

#### **Conversion coating containing chrome**

*Conventional techniques have been deleted if they can no longer be considered BAT*

*This does not prohibit their use or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumption or emissions.*

##### **Description**

Chromate conversion coatings can be applied over phosphate conversion coatings used on ferrous substrates. The process is used to enhance the phosphate coating. Chromating is also often performed on (electro-) galvanized parts to make them more durable.

Conversion coatings including hexavalent chromium conversion with substitution and control techniques are discussed in the STM BREF [59, EIPPCB, 2006].

##### **Current situation**

*Conversion coatings in coil coating have traditionally used Cr(VI) (chromate) rinses widely, after the pretreatment and/or surface preparation (e.g. brushing) and before painting. However, under the REACH Regulation [REACH 2006], the Cr(VI) compounds used in such rinses have a 'sunset date' of 21 September 2017, and as they are listed as Annex XIV substances will require specific authorisation for each use.*

*At the time of this draft, applications for authorisations have been registered, but one has been approved. BAT conclusions have been based on the possibility of likelihood of continued use for in the aerospace industries and possibly for certain coil-coated products.*

### 17.7.1.2 Chrome-free conversion coatings

*TWG please update the Description*

*This technique is described in the STM BREF*

#### Description

Some chrome-free conversion coating systems are available, based on treatments with composites organic-zirconium fluoride solutions, titanium fluoride, tartrate, phosphoric acid, or treatment with organic silicon derivatives (silanes). They may require a subsequent polymer layer to achieve the required corrosion resistance.

In the vehicle manufacturing industries, e-coat immersion prime coating is applied directly over the phosphate layer without chromating to achieve high quality corrosion protection.

The chrome-free pretreatment with titanium, phosphoric acid and organic polymer has been further developed with a chemical provider for the usual spray and dip processes. Since 1998, a company has used the method successfully in coil coating machines.

Chromium-free conversion coatings are now in use for anodising in the aircraft industry, based on tartrate and phosphoric acid.

#### Bath maintenance and the reduction of water use, wastes and waste waters

*These techniques and other associated BAT are described fully in the STM BREF*

### 17.7.2 Material-based techniques [Paint systems]

#### Conventional Solvent-based paints

*Conventional techniques have been deleted if they can no longer be considered BAT*

*This does not prohibit their use or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumption or emissions.*

*Check*

#### Description

Use of conventional solvent based paints — Liquid paints and coating materials with organic solvents

#### Technical description

#### Environmental performance and operational information

#### Cross-media effects

#### Technical considerations relevant to applicability

#### Economics

#### Driving forces for implementation

#### Example plants

#### Reference literature

### 17.7.2.1 High solid content solvent-based paints / coatings / inks / adhesives

*ESVOC consider this technique important*

#### **Description**

Paints / coatings / inks / adhesives containing a low amount of organic solvents and increased solid content

#### **Technical description**

The solids content amounts to more than 65 vol-%, for example, in yacht coating 450 g/l epoxies are used for under waterline areas; solid contents of 70 – 95 % are applied in coil coating processes. The film formers used are mainly based on epoxy, two-component (2-K) polyurethane, polysiloxane, oxirane or alkyd resin.

#### **Environmental performance and operational information**

The use of higher solids paints reduces solvent use compared with conventional, solvent-based paints, while still applying the requisite amount of coating. Reductions in extracted VOCs place a lower demand on the abatement equipment. Reduced solvent loadings within the ovens may allow reductions in extracted airflows or increased line speeds for a certain concentration in the air. This reduces the use of gas in the oxidiser, reduces the use of solvents and lowers the volumes to transport.

#### **Cross-media effects**

~~No data submitted.~~ The reduction of solvent vapours in the waste stream may increase the demand for gas/fossil fuel in the oxidiser, and/or reduce the energy recovered for preheating the oven air.

#### **Technical considerations relevant to applicability**

For paints used for the painting of agricultural and construction machines or household devices, high solids based on acrylate and polyester isocyanate are mostly used.

Widely applicable.

In the coating of ships and yachts, high solid epoxy coatings are commonly applied onto the underwater parts of ships and yachts.

In the coating of aircraft, high solid coatings are sometimes applied in the topcoat.

In the coating of trains, high solid-based paint is only applied in the one-coat topcoat.

In the coating of buses, high solids are applied in the one-coat topcoat system.

In coil coating, high solids are commonly applied.

They are not currently applied in metal packaging.

They are not currently applied in the coating of wood and furniture because they are too sticky and result in an undesirable 'plastic-like' aspect of wood-based product surfaces coated

#### **Economics**

Purchasing costs of high-solid paints are higher compared to conventional paints, but as they have higher coverage, the cost per m<sup>2</sup> is usually lower. Savings can be expected on labour costs.

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

Widely used.

**Reference literature**

[13, DFIU and IFARE, 2002] [11, InfoMil, 2003, 38, TWG, 2004] [78, TWG, 2005]

**17.7.2.2 Water-based paints / coatings / inks / varnishes and adhesives**

*ESVOC consider this technique important*

**Description**

Using paints, coatings, liquid inks, varnishes and adhesives where organic solvent is partially replaced by water.

**Technical description**Paints

Water-based paints contain water-based or water-dispersible film forming agents. Water-based paint systems can be one-component paints; however mainly two-component and UV radiation curing paints are applied. They are mainly based on alkyd, polyester, acrylate, melamine and epoxy resin. Water-based powder and powder slurry coatings are discussed in Section 17.7.2.8 and Section 17.7.1.7 respectively.

Water-based paint systems normally have a water content of 10–65 wt-% and often also contain < 3–18 % organic solvents as a solubiliser and for an improvement of the properties of the wet film layer. Completely organic solvent-free paints are also available. Biocides may be part of the formulation as preservatives for the storage of the paints, in architectural applications and for electrocoat (which is kept and used in tanks).

The main improvements of these materials are their corrosion protection and exterior resistance (against climatic impacts).

Two-component water-based paints show an improved resistance, especially mechanically, and also shows a very good isolating function even on woods rich in natural oils.

Adhesives

Water-based adhesives do not contain organic solvents.

**Environmental performance and operational information**Paints

The main advantages of water-based paints are the reduction of VOC emissions and the possibility for recycling of the paint in use in certain applications, e.g. using ultrafiltration. Cleaning of spraying devices and other tools can be carried out with water/solvent mixtures with a solvent proportion of about 5 % to 20 %.

Water-based paints can cause significant corrosion problems in storage, pumping and application equipment, especially spraying systems, due to the presence of water and oxygen. A substitution with water-based paint for conventional installations usually requires significant modification of the facility, such as replacement of the paint supply lines by materials made of high-grade steel.

There may be problems with corrosion, and in the ovens and exhaust ducting.

Increased blocking of spray equipment is reported in the coating of furniture and wood. It is not known if this is a process problem or can be solved by training and adaptation.

*TWG: please confirm*

If water-based paints are processed, the following requirements generally have to be met:

- the ambient temperature has to be between 18 °C and 28 °C;
- the surface temperature of the workpieces may not be lower than 15 °C;
- an optimum processing is given at air humidity between 55 % and 75 %;

- water-based paints may not be stored below 0 °C (frost damage);
- good airflow across to the surface.

Since water-based paints have lower application efficiencies, paint consumption may be increased. However, in practice, reduced transfer efficiency is valid for high rotation electrostatic bell application if external charging is used (5 % less as the maximum). Reduced transfer efficiency may occur in electrostatically assisted manual application where voltage is limited for safety reasons. Alternative techniques (internal charging) are available and widely used. As waterborne coatings are mostly used in new or redesigned installations, efficiency is usually improved due to better performance of equipment and possibly higher 'right first time' rates. Evidence from automotive applications shows comparable transfer efficiencies with solvent-based systems.

Compared to organic solvents, water has higher evaporation energy. Therefore, the energy demand for the drying of water-based paints may be expected to be higher, if the same drying rate as for solvent-based paints has to be achieved. However, compared to atomisation, acclimatisation of spray booths, heating of substrates, oven losses, etc. the energy demand for evaporation of volatile compounds is only in the range of 1 % for many industrial processes. Water, instead of organic solvents, has a minor impact on total process energy. The additional energy requirement is only significant for drying at ambient conditions and in the case of wet-on-wet processes.

Water-based systems usually use amines for pH stabilisation. ~~Experiments with these amines in~~ One company ~~have~~ encountered major problems with these amines concerning employee protection. (*From coil coating*)

Water-based systems can present difficulties in cleaning operations on the coater equipment, demanding more powerful cleaning agents than solvent-based coatings.

### Adhesives

Water-based adhesives eliminate related solvent emissions.

### **Cross-media effects**

#### Paints and inks

Coil coating: Due to the solvent content of about 10–35 %, and the high yearly load, a waste gas treatment is needed ~~with the related high energy consumption~~. Thermal WGT may require additional NG to achieve emission levels.

There will be increased BOD and COD in the waste water, and substances such as biocides, organotin catalysts and ammonia which have to be treated accordingly.

Depending on the systems used, the amount and quality of hazardous waste may change significantly. *TWG please confirm if increased or decreased*

### Adhesives

Higher energy is required for drying.

### **Technical considerations relevant to applicability**

#### Paints

For many years, water-based paints have been available on the market and are widely used. Due to the permanent development of these materials, their range of application is steadily increasing.

They are commonly applied in the vehicle coating industry. In the coating of trucks and commercial vehicles, they are commonly applied in cathodic dip coating, primer/filler and in base coats on commercial vehicles, truck cabs and chassis and on axles. In the coating of buses, water-based paints are used in some cases (cathodic dip coating and underbody protection).



With one exception, water-based paints are not applied as topcoats. In only one installation, city buses are completely coated with water-based paints.

In the coating of plastic workpieces, water-based coating systems are commonly applied in ground coat, base coat and sometimes in the clear coat.

In the coating of trains, two-component chromate-free water-based paints based on epoxy are applied in the groundcoat, primer/filler and sometimes in the topcoats. Water-based paints are also applied for protection of the underbody.

In the coating of agricultural and construction equipment, they are commonly applied in cathodic dip coating and also in one-coat topcoats.

In the coating of ships and yachts, although water-based paints are available for several applications, they are used only in a limited number. Water-based applications use airless spray or roller, and not high rotation electrostatic bell.

In the coating of aircraft, they are not currently applied because of their low resistance against chemicals such as hydraulic oil. Since the manufacturer's corrosion protection guarantee lasts for 25 years, only specific, approved paint systems can be utilised

In coil coating, if water-based coatings are used, the application is mostly limited to primers and backing coats.

In the coating of metal packaging, water-based paints are used, however, they contain up to 38 % organic solvents. External drum coating uses water-based coatings with < 10 % organic solvents.

In furniture and wood, two-component and UV curing water-based paints are commonly applied in some flat furniture parts before assembly. However, there are technical limitations, such as fibre swelling, depending on substrate. When switching to water-based products the total volume of products to be dried increases, since more painting and drying steps are needed, with additional intermediate sanding and polishing. Both sanding and additional drying result in an increased energy use, raw material use as well as increased labour. As an alternative, other types of drying systems could be introduced. This may need new development work and would increase costs. The finishing of assembled furniture is not possible with UV.

~~This technique is not widely applied for ships.~~

In the manufacturing of adhesive tapes, water-based adhesives are applicable in new and existing plants and installations. They are suitable for the lower quality range of packaging and masking tapes as well as for double-sided tapes.

### **Economics**

Water-based coating systems do not cause major cost increases in use. Replacement of equipment with stainless steel alternatives to counter corrosion is typically more expensive.

Costs for changing existing automated painting lines may be very high in some cases. Retrofitting is usually done at the end of the technical lifespan of the existing installation. Where painting is applied manually, costs for retrofit are less but still significant, and will depend on the ratio of manual to automatic equipment

### **Driving force for implementation**

~~Another advantage is that there are~~ No flashpoint hazards associated with such paints, minimising the risks of combustion and explosion. **TWG please confirm**

### Example plants

Widely used.

### Reference literature

[13, DFIU and IFARE, 2002] [14, DFIU and IFARE, 2002] [8, IFARE and CITEPA, 2002] [11, InfoMil, 2003] [38, TWG, 2004] [78, TWG, 2005] [116, ESIG, 2005] [27, VITO, 2003] [96, Presti, 2005]

### Water-based coatings with reduced flash-off requirement

#### **ESVOC propose deletion**

**Description:** For development from to water based coatings, see Operational data, below. The base coat systems show similar characteristics to current water dilutable systems.

**Achieved environmental benefits:** Energy consumption may be lower than conventional solvent systems, and lower than for the application of conventional water dilutable base coat systems (no infrared drier is necessary).

**Cross-media effects:** No data submitted.

**Operational data:** Standard waterborne base coats need tight control of spray booth operating conditions, good climate control of spray booths (with a narrow operation window), five to six minutes enforced flash off, and stainless steel pipelines. The flash off requirement in particular hinders the application of waterborne coatings used in existing installations. For reduced flash-off base coats, 90 to 150 seconds flash off time are sufficient (rapidly drying resins, highly volatile and azeotropic co solvents and high speed blowing zones), so they fit into many existing lines. At the same time, the operating window is enlarged.

**Applicability:** The use of this concept is restricted by the following paint layer. Tests have shown that good surface quality results are attainable with a 2 component clear coat, whereas with 1 component clear coat systems, some quality imperfections (e.g. cloudiness) may still appear. Successful line trials have been performed. Approvals exist with 2 component as well as with 1 component clear coat.

**Economics:** The solvent based base coat can be changed over to a water dilutable base coat with relatively small technical expenditure (compared with a new plant).

**Driving forces for implementation:** No data submitted.

**Example plants:** Products with reduced flash off time are in commercial use at Hyundai Assam, South Korea and at Alfa Romeo Pomigliano, Italy.

**Reference literature:** [78, TWG, 2005]

### 17.7.2.3 Electrocoating

#### **Important**

#### **Description**

Paint particles are dispersed in a water-based solution and deposited on immersed substrates under the influence of an electric field (electrophoretic deposition). It is a specific type of dip coating.

#### **Technical description**

This is also known as electropainting, electrophoretic dipping, e-coat, ELPO, cataphoretic dipping, etc.

Pretreated vehicle bodies are electrically charged while being passed through a bath of electro-immersion coating. The solids components of the E-coat paint are deposited on the car body by an electrophoretic process. Through this process, it is possible to coat all interiors and exteriors of the car bodies including all cavities. The calculated ecoat area is typically between 70 and 130 m<sup>2</sup> per vehicle, depending on size and design.

It is necessary to distinguish between cathodic or anodic deposition. Cathodic dip coating is widely used and is able to fulfil the high quality requirements.

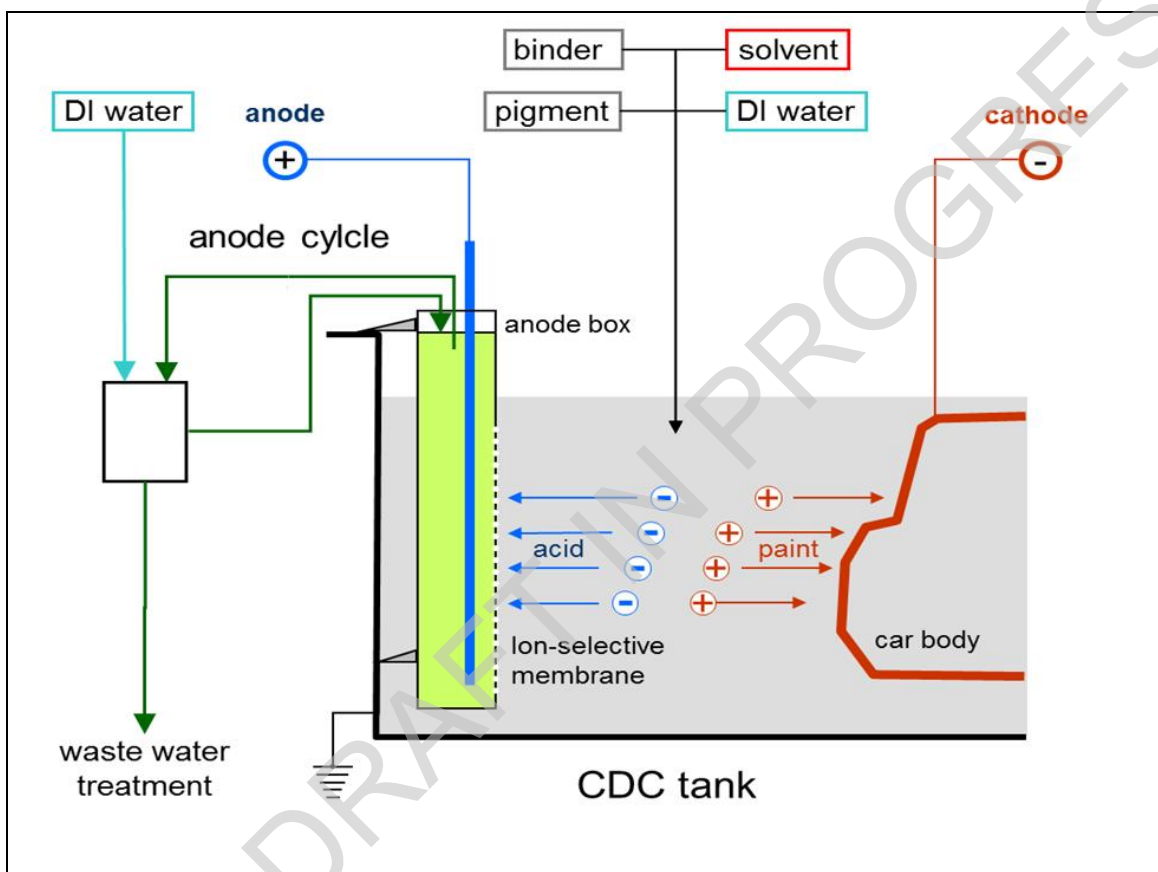


Figure 17.8: Electrocoating process

The coatings are typically water-based and are diluted with deionised water. They are usually based on amine-functional modified epoxy resin.

The combination of paint resin and deposition process creates a very resistant film after baking that makes a substantial contribution to corrosion protection for interior and exterior.

The solvent content of the e-Coat paint is typically in the range 2–4 %.

The coating process is followed by a multistage cascade rinse to remove paint particles that have not been electrodeposited. The rinsing medium is cleaned via ultrafiltration. The paint components concentrated in the retentate are fed back into the CDC tank, the filtrate (water and low-molecular CDC chemicals) can be reused in the rinse cycle. Optionally, the paint transported from the last DI rinse stage can be separated and fed back into the treatment bath.

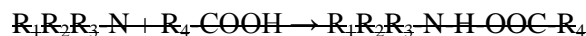
~~This is also known as electropainting, electrophoretic dipping, e coat, ELPO, cataphoretic dipping, etc. In the water based paint tank, a direct electric current is circulated between the workpiece which forms one electrode and the electrodes of the opposite polarity which are~~

located in the tank. A stable protective film is deposited. According to the polarity of the workpiece, anodic (anaphoretic) or cathodic (cataphoretic) electrocoating will take place, with different characteristics. There is the possibility that in anodic coating, the substrate has some metal loss leaving the fresh metal surface in an acidic surface layer which can be readily oxidised (i.e. corroded). This does not happen with anodic systems, which are now the most widely used, contributing to modern high corrosion resistance coating systems (essential as part of quality standards, e.g. for cars).

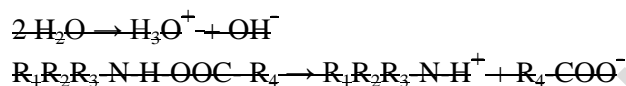
The electrolyte contains the positively charged particles of suspended paint pigments and bases (as a polymer resin) and negatively charged particles of anions of an organic acid  $R-COOH$  (usually acetic acid, where  $R = CH_3$ ).

In the solution (or better, colloidal suspension) the acid anions (in a suitable ratio) are attracted to the soluble resin particles which have a high charge density. Resin particles are formed by high molecular weight tertiary amines (in general  $R_1R_2R_3-N$ ) which, in the organic acid solution, react to form quaternary ammonium ions with a positive charge.

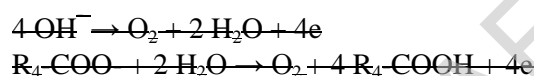
The initial reaction in preparation of paint:



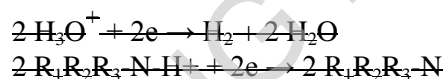
Dissociation processes occurring in solution:



Electrochemical processes occurring at the anode:



The positively charged colloidal particles move in the conducting solution (with its applied potential (voltage)) by electrophoresis to the (negative) cathode. In the first step, the following electrochemical processes occur at the cathode which, in a pH neutral solution, form an alkaline diffusion layer at the anode surface (with a pH of between 12 and 14):



The particles are deposited by electrodeposition as the cations (resin and pigment) react with the hydroxyl ions to become insoluble. Finally, as the paints solids are precipitated at the cathode, the water is driven from the vicinity of the cathode through the semi porous film by electroendosmosis. The overall effect is to form a physically durable strongly adhered film. Because the film has a relatively high resistance, the process stops itself when the film thickness is nearly equal on all surfaces and edges.

The drag out contains non deposited paint which must be readily rinsed off to achieve high quality in the following coatings.

### Achieved environmental benefits

With the introduction of two-component ecoat paints (binder solution and pigment paste) the solvent content could be minimised. Due to the low solvent content of this material and the fact that the material is not atomised as with spray operations, VOC emission levels are very low.

Typical emissions are between 2 g and 4 g VOC/m<sup>2</sup>, depending on the electrocoated surface area of the car being painted. With abatement of waste gas from the oven, < 1 g VOC/m<sup>2</sup> can be achieved.

All electrocoatings used are lead-free.

A very high proportion of paint dragged out in rinsing is recovered (nearly 100 %), by combining reverse cascade rinsing with membrane filtration,

In addition to the paint consumption being low, a small amount of waste is generated.

Dip coating represents a very high application efficiency and because of the low material usage generates very little waste.

~~All used electrocoatings are water based and lead free (lead is replaced by yttrium or bismuth); their content of organic solvents amounts to approx. 2–6 %. When combined with reverse cascade rinsing with membrane filtration, a very high proportion of dragged out paint is recovered (nearly 100 %).~~

### Cross-media effects

~~Possible increase in waste water flows. The paint suspension may contain organotin compounds as catalysts, other ecotoxic compounds, although these are largely retained in the process with the paint solids recycling system. The effluent also contains a substance with COD (1000 to 5000 mg/l were emitted from the rinsing processes) and BOD 200 to 1000 mg/l (1–3 g/m<sup>2</sup> COD and 0.2–1 g/m<sup>2</sup> BOD). 90 % of the COD and 99 % of the BOD can be eliminated by physico-chemical treatment followed by biological treatment.~~

### Environmental performance and operational data

Application takes place in a purpose built facility with air extraction ventilation. The e-coated bodies must pass through an oven before subsequent coatings are applied.

Coating is performed in an enclosed dip tank. The deposition voltage lies between 300 V and 450 V. At high amperages, an energy amount of 5 kWh to 10 kWh per vehicle body is input into the CDC bath. Due to this deposition process and the friction heat from the pumps, the dip coat bath heats up and must be cooled to < 30 °C with the help of a paint cooling system. Electro-dip paints are constantly stirred in the dip tank in order to avoid a settling of pigments, fillers, and binders.

The advantages of electrocoating are:

- ~~• the consistent and complete coating with uniform thickness (even in cavities) with no forming of edge runners. This is because, in part, the process inherently limits the film thickness~~
- ~~• the parameters can be controlled by the voltage (potential) applied, coating time and bath solids (within process limitations)~~
- ~~• a high efficiency process with the possibility of full automation.~~

The disadvantages are:

- ~~• the essential high level of maintenance of the paint tanks for quality assurance~~
- ~~• high capital costs of installing a complete system.~~

~~Use of cascade techniques and ultrafiltration for the rinsing tanks of electrocoating is common practice (see Section 17.11.8). More information can be found in the STM BREF [59, EIPPCB, 2005].~~

### Technical considerations relevant for applicability

This technique can be used for whole vehicle bodies and metal components (as well as non-automotive) including inside cavities and other surface areas that are difficult to reach, as the technique has a high throw power.

At present, this immersion technique is widely used, but only for the application of the e-coat (cataphoretic application). The optical quality of the lacquer finish is very important in car production, therefore only spraying techniques are used for the application of primer and topcoat.

~~It is commonly applied in the automotive industry, for the coating of buses, coating of agricultural and construction equipment and for the coating of trucks and commercial vehicles.~~

~~It can be applied to metal components, even mixed metals such as some alloys and subassemblies with brazing or welding. It is also widely used for coating a variety of small components.~~

~~This technique is currently not applied in the coating of aircraft, trains, ships and yachts.~~

### **Economics**

As electrocoating is usually highly automated and provided complete with countercurrent multiple rinsing systems and membrane filtration to recover the dragged out paint, there are usually high investment and material costs.

### **Driving force for implementation**

Low workplace safety impacts.

### **Example plants**

Widely used in the vehicle production industry; all VW plants, CROPUSA, Burgos, Spain (for components).

### **Reference literature**

[13, DFIU and IFARE, 2002] [59, EIPPCB, 2005][78, TWG, 2005] [127, France and TWG, 2003 ] [128, CzechRepublic, 2006] [129, ACEA, 2003], [VDI 3455]

### **17.7.2.4 Radiation-cured ink coatings, paints, varnishes and adhesives [Radiation curing paints]**

*ESVOC consider this technique important*

#### **Description**

Inks, coating materials, paints and adhesives that are cured without heat and without emission of VOCs by the activation of specific chemical groups by UV or IR radiation, or fast electrons

#### **Description**

Radiation curing coatings rely, for their cure, on the activation of particular chemical groups by UV light or fast electrons (see Section 17.8.5). This property can be found in both resins and liquid diluents, thus it is possible to produce liquid coating systems that cure and harden without heat and without any emission of VOCs. Alternatively, similar chemical functionality can be incorporated into water-based, or even solid (powder) coatings. The base resins include epoxy, polyester, polyurethane but all with acrylic or vinyl functionality. The curing reaction is initiated directly by electron beam radiation (EB) or by ultraviolet (UV) radiation via an added photo-initiator.

For more information on:

- UV (ultraviolet) radiation curing: see Section 17.8.5.2;
- EB (electron beam) radiation curing: see Section 17.8.5.3.

**Achieved environmental benefits**

Neither water-based nor solvent-free radiation curing paints generate waste water or VOC emissions.

**Cross-media effects**

No data submitted.

**Operational data**

UV curing paints can be applied by several techniques, such as brushing, rolling, casting, spraying and vacuum coating. Radiation cured powder coatings are being developed, but the majority of the powder coatings are cured in conventional high temperature ovens, see Section 17.7.2.8.

**Applicability**

Widely applicable.

In the coating of metal packaging, UV cured coatings are widely applied in three-piece can manufacturing. However, it is not applied in DWI can and aluminium tube manufacture.

In the coating of plastic workpieces, UV cured coatings are applied in clear coats, e.g. on wheel covers.

In furniture and wood painting, UV cured water-based coatings are commonly applied in some furniture and wood coatings. This is usually where flat panels can be separately coated and the coating is carried out prior to assembling furniture.

They are currently not applied in the automotive industry, in the coating of aircraft, ships, trains, buses, agricultural and construction equipment, trucks and commercial vehicles and in coil coating (see also Section 19.14.2).

**Economics**

Costs will depend on specification, quantities and supplier. As an example, costs for UV water-based paints (about 50 % solids) are about EUR 6.50 per kilo, which is more than conventional paints (e.g. two-component PU-paint costs EUR 4.35 per kilo). However, with pure UV cured paints (which are 100 % solids) the overall costs per m<sup>2</sup> will be lower because with the high solid content a higher efficiency will be achieved and at least 50 % of the overspray can be reused.

The approximate price per kilo for UV curing powder coating is in the range EUR 3.01–5.38.

Investment costs for a new UV curing powder coating unit are about EUR 875 000 – comprising about EUR 275 000 for the application booth and drying installation and EUR 600 000 for automation, material buffers, conveying system, etc. Operational costs are more or less the same as a conventional existing solvent-based application unit.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [27, VITO, 2003, 38, TWG, 2004] [105, CEPE, 2006]

**17.7.2.5 Solvent-free two-component adhesives****Description**

Two-component solvent-free adhesive materials including a first component which acts as a resin and a second component which acts as a hardener.

#### **17.7.2.6 Hot melt adhesives**

*copy/paste from adhesive tapes chapter*

##### **Description**

Hot melts do not contain solvents.

##### **Achieved environmental benefits**

Solvent emissions are eliminated.

##### **Cross-media effects**

No data submitted.

##### **Operational data**

No data submitted.

##### **Applicability**

Applicable in new and existing plants and installations. In the manufacturing of adhesive tapes, hot melts are suitable for the lower quality range of packaging and masking tapes as well as for double-sided tapes.

##### **Economics**

No data submitted.

##### **Driving force for implementation**

No data submitted.

##### **Example plants**

No data submitted.

##### **Reference literature**

[14, DFIU and IFARE, 2002]

#### **17.7.2.7 Water-based adhesives**

*copy/paste from adhesive tapes chapter. merged with:17.7.2.2*

#### **17.7.2.8 Powder coatings – conventionally cured**

*Important*

##### **Description**

Solvent-free paint applied as a finely divided powder and cured in thermal ovens.

##### **Technical description**

Powder coatings are solvent-free materials that consist of powder with a particle size in the range 25–60 µm. Section 17.7.2.4 discusses the development of radiation curing of powder coatings but the majority of the powder coatings are cured in conventional high temperature ovens.

The main film forming agents are polyester or epoxy resins. The powder particles are normally applied by electrostatic charging in spray guns or a cloud chamber and are then attracted to the earthed ~~metal strip~~ substrate as it passes.



To cure, the material is heated in a convection oven where it melts and fuses into a film.

However, there are also the following disadvantages:

- The control of the film thickness is difficult (see Operational data, below). For example, in the automotive industry, a higher layer thickness (approximately 65  $\mu\text{m}$ ) will be created than is necessary, which results in higher paint consumption; however, increasingly nowadays, thinner layers (approximately 55–60  $\mu\text{m}$ ) are also achievable.
- Higher curing temperatures (approximately 140–200  $^{\circ}\text{C}$ ) are necessary and because of this the technique cannot be applied to all substrates. However, low temperature powder coatings are becoming more readily available which cure at temperatures of around 60–100  $^{\circ}\text{C}$ .
- Application conditions are strictly defined (temperature, humidity).
- Manual application is only possible if certain safety regulations (against dust, electrostatic voltages) are met.

### **Operational data**

The subject of film thickness in powder coatings is not a simple one. The possible applied film thickness range is limited by the particle size distribution of the powder as well as by the application speed and cure conditions. Thus, it is technically possible to apply as thin a coat as 5 microns, but the powder needs to be very finely ground and precisely controlled. This is a very expensive operation. In addition, these very fine powders have poor flow and transport properties so they are difficult to apply. Powder coatings capable of application at 30 microns are certainly available for some end uses. At the other extreme, very thick coatings can be applied by powder sintering, but here, the limitation is the time taken for heat transport to melt, flow and fuse the powder. If the formulation is thermoset (heat hardening), the surface may be cured before full melting and fusion has occurred, trapping air bubbles within the film. Unless demanded by a particular end use, film thicknesses of over 90 microns are unusual simply on the basis of economics.

### **Environmental performance and operational information**

Powder coating systems show the following positive properties:

- almost free of solvent emissions;
- there is a potential for reduced gas consumption, as exhaust incineration may no longer be needed;
- no water is necessary in order to absorb lacquer particles in the paint booth;
- no waste water is produced, so no treatment and use of additives (such as coagulation agents) is necessary;
- low waste generation if the possibility of paint recycling is used;
- paint recycling is technically possible (up to 95 %) and necessary for economic reasons
- high application efficiency, up to 100 %;
- application tools and the complete booths can all be cleaned by vacuum cleaning or by blowing with compressed air; in this way, resources are saved and solvent emissions are avoided;
- the high proportion of circulating air in the paint booth results in a reduction of energy consumption.

There are possible occupational health risks due to, e.g. mutagenic substances such as triglycidyl isocyanurate (TGIC) being used.

There may be potential electrostatic hazards

~~The application of powder coating generates neither waste water nor significant VOC emissions.~~

The powder paint technology applied via electrostatically assisted spraying does not require a recapture of overspray paint particles by water.

### **Cross-media effects**

Film thickness limitations will increase the quantities of coating materials used. The development of reaction products emitting odour in the curing oven during the fusion and reaction of the powder could require the continued use of an abatement technique necessary anyway.

High curing temperatures are required. However, curing by combinations of infrared and air circulation techniques has a higher energy efficiency compared to conventional curing techniques.

Some low levels of VOCs may be emitted on curing – due to the reaction chemistry.

### **Technical considerations relevant to applicability**

In several sectors, the application of powder coatings is already a well-established technique. Regarding environmental advantages, there are possibilities for automation and good profitability due to the possibility of recycling the overspray, and the use of powder coatings is continuously increasing. Powder coatings require electrostatic application techniques and are, therefore, primarily suitable for metal.

In the automotive industry, powder primer and clear coat is no longer used ~~used in only one plant in the European industry~~, see Section 2.4.3.2, although it is more widely used in the US. Currently, as well as the operational problems associated with process change (such as maintaining the correct colours and finish), a powder coat system does not meet most European manufacturers quality specifications.

They are currently not applied in the coating of aircraft, ships, trains, buses and trucks and commercial vehicles, only in coating components (as in Chapter 3 on coating of plastic workpieces and other metal surfaces ~~and in Chapter on coating of plastics~~). In the coating of plastic workpieces, it is currently only applied in small batches in the coating of small parts, such as composite parts of metal and plastics for car radiators.

The reason that the techniques is not applied for coating of aircraft and ships is that a forced drying step is needed, and in these industries could therefore only be applied to components small enough to be enclosed.

In the coating of agricultural and construction equipment, one manufacturer is currently building an installation for powder coatings. This production line will replace a conventional, solvent-based, two-component one-coat topcoating. This technique is ready for the serial production of agricultural and construction equipment.

In coil coating, powder coating is only used to a limited extent ~~in the coil industry~~, because of difficulties of speed and control. They are especially used for construction sector products, e.g. for flat panels, window frames, sanitary cabins and by the sheet metal processing industry.

In the coating of metal packaging, powder coating may be applied onto the welding of three-piece cans. However, not on the coating of DWI cans.

In furniture and wood painting, it is currently only successfully applied onto MDF.

### **Economics**

Costs will depend on specification, quantities and supplier. Currently, the price for powder coating systems is still higher than for conventional coating systems. The price per kilo was in the range EUR 3.01–5.38 (2006).

Retrofitting a conventional solvent-based application unit with a powder coating unit, only requires replacement of the paint application systems; the ovens may not need to be changed. However, in the automotive industries, powder coatings require completely new spray booths, supply systems and curing ovens.

#### **Driving force for implementation**

#### **Example plants**

No data submitted.

#### **Reference literature**

[13, DFIU and IFARE, 2002] [27, VITO, 2003] [38, TWG, 2004] [78, TWG, 2005] [105, CEPE, 2006] [116, ESIG, 2005] [42, Envirowise, 2003] [43, Envirowise, 1998]

#### **Powder slurry**

*ESVOC propose deletion: is it used in Other Metal Surfaces?*

**Description:** Powder slurries are powders dispersed and stabilised in water and are applied using conventional equipment for liquid paints. They can be used in clear coat application.

**Achieved environmental benefits:** The application of a powder slurry coating generates neither waste water nor VOC emissions. In the automotive industry, significant energy savings are achieved by substituting the conventional 2-component clear coat by the wet-in-wet applied powder slurry clear coat. With the wet-in-wet application, the intermediate drying step can be missed out.

**Cross-media effects:** No data submitted.

**Operational data:** A forced drying step is needed.

**Applicability:** This technique is currently only applied in the coating of cars, see Section 0.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002]

#### **17.7.2.9 Pre-coated materials**

*ESVOC considered it as Important*

#### **Description**

Materials coated before cutting and/or shaping and/or assembling.

#### **Technical description**

Pre-coated materials can be used in the assembly of products, reducing the number of paint coatings or eliminating the need to paint. In the case of coating substrates of uniform dimensions, such as coil-coated metals, wood or fibre boards, etc. coatings can be applied using techniques which are more difficult to apply to the assembled products or part-products, but are more environmentally beneficial (see Section 17.7.3).

#### **Achieved environmental benefits**

Significant reduction of VOC emissions dependent on the spraying activities that are replaced by applying coil-coated materials. More efficient use of materials. More efficient drying or

curing. More efficient collection and destruction of emissions during coil coating, as the application of the coatings and extraction of waste gases for a continuous flat surface is easier and more efficient than for coating formed components and bodies.

### **Cross-media effects**

None. Although the emissions are transferred to the coil coating producer, they are reduced, see Achieved environmental benefits, above.

### **Operational data**

Pre-coated materials are produced by coil coating, see Chapter 6.

### **Applicability**

Coil-coated metal is usually supplied complete with finish coat, but can also be supplied in primer ready for subsequent coat(s). It is used for a growing number of applications including: building and construction products, electrical appliances (white goods), automotive industry, caravans and mobile homes, metal cabinets, etc.

In the coating of trains, coil-coated materials are increasingly used for the production of freight wagons.

In agricultural and construction equipment, some manufacturers apply electrocoating and topcoating before assembly takes place; coil-coated materials might be an option here.

In the coating of metal packaging, coil-coated materials are commonly used in three-piece can manufacturing.

### **Economics**

Reduction in production steps and concentration on core business.

### **Driving force for implementation**

Reduction in emissions to the workplace and environment.

### **Example plants**

Widely used. EMPAC, ECCA

### **Reference literature**

[13, DFIU and IFARE, 2002, 38, TWG, 2004] [78, TWG, 2005]

### **17.7.2.10 Laminate film coatings**

*Copy/Paste from Coil Coating Chapter:*

#### **Description**

Polymer films applied onto a coil or web in order to give aesthetic or functional properties.

#### **Technical description**

For some specific end uses, solvent-free, solid polymer films are applied to coil coating plants. These films may be based on a number of polymers including:

- PVC (polyvinyl chloride);
- PVF (polyvinyl fluoride);
- PET (polyethylene terephthalate);
- acrylics;
- polypropylene.

In some cases, the films are coloured or opaque and may be decorated with printed patterns. In others, they are clear films offering specific properties of hardness, stain resistance, etc. In

almost every case, the film is applied over a liquid paint base coat or adhesive layer. Specific equipment is needed to laminate the plastic film onto the strip.

### **Environmental performance and operational data**

Films are applied by a pressure roll onto a preheated coating of appropriate base coat/adhesive, usually immediately on exit from the curing oven.

The relative environmental performance (versus standard paint) depends on the final composition of the coating system. If the film is used instead of a normal paint layer, glued onto the web with preheated adhesive, there is no evidence of a better environmental performance than liquid coil-coating. When the laminated film is applied on the top of a paint system, then the overall raw material and energy consumption can be significantly lower.

**TWG: Please confirm 'The relative environmental performance' refers to the relative solvent emissions and energy consumption.**

~~There is no difference between coating with paint or applying a laminate with an adhesive, as normally adhesives have higher content of solvent than in paints.~~

~~Elimination of solvent from one layer in the coating system preventing the emissions of solvent to the air.~~

The comparison between a standard paint (primer and finish coating) and a foil coating in use shows a longer life for foil coating than the paint coating because the thickness of the film coating is normally higher than the paint coating and because of this more resistant.

### **Cross-media effects**

The polymer films are produced off site by an extrusion or calendaring process. The ordered width rarely matches the exact dimensions of the coils to laminate. The excess film is side trimmed and is a process waste.

### **Technical considerations relevant to applicability**

Generally used for very specific end use properties. Cannot compete with liquid coil-coating for all standard cases.

### **Economics**

The process needs specific equipment. If this equipment was not installed at the time the line was built, it can be difficult and expensive to retrofit.

Laminated films are more expensive than conventional liquid coatings. The process is only of interest when some specific function is required that is difficult or impossible to reach with liquid coating.

### **Driving force for implementation**

Product specifications and innovation.

The process opens the possibility to deliver some niche products for specific purposes.

### **Example plants**

No data submitted.

### **Reference literature**

[22, ECCA, 2004] [ECCA 2017]

### **Paints containing toxic metals**

*Combined with 17.6.1*

**Description:** ~~Paint pigments have contained toxic metals such as cadmium, hexavalent chromium, nickel and lead for the colour of their compounds and for corrosion resistance.~~

However, their use is now strictly limited by regulations to activities which are not in the scope of this document, see Section 0.

**Achieved environmental benefits:** No data submitted.

**Cross-media effects:** Toxic materials in the environment.

**Operational data:** No data submitted.

**Applicability:** Specialised applications such as restoration, etc. are not in the scope of this document.

**Economics:** No data submitted.

**Driving forces for implementation:** Workplace health and safety. Marketing and use regulations. Product and wastes legislation.

**Example plants:** No data submitted.

**Reference literature:** [52, COM, 2000]

### 17.7.3 Paint application processes and equipment

Processes with a high application efficiency include filling, rolling, casting, dipping, flooding and vacuum coating. These processes generate less overspray than spray applications but are not universally applicable. There are two dipping processes: conventional and electrocoating.

Spraying may be with or without electrostatic assistance. For electrostatically assisted spraying, an electric field is generated between the workpiece and the spray gun. Then the following advantages concerning the environment as well as coat effectiveness are reached:

- lower material consumption, lower emissions, smaller amounts of paint sludge and a reduced soiling of painting areas (less cleaning);
- improved possibilities for automation of painting processes, faster coating and, therefore, a higher productivity;
- less air consumption (less energy demand).

Disadvantages of electrostatically assisted spray applications are the risk of edge runners and layer thicknesses which are too deep into cavities and interior edges due to a concentration of paint materials onto these areas. Several electrostatically assisted spray applications are in use, and they are described in the following sections. Also there may be special requirements concerning quality achieved, geometry, paint materials, electrical conductivity (e.g. affecting the ability to recoat surfaces) and workplace safety relating to the high voltages used.

Despite the increasing use of electrostatic application techniques, spraying without electrostatic charge is still widely used for various applications. In comparison to electrostatic processes, the investments are significantly smaller. Also there are no special requirements concerning geometry, paint materials, electrical conductivity and workplace safety. The disadvantages of these application techniques are low efficiencies. Thus, several techniques were developed for a minimisation of the overspray and their efficiency is comparable to electrostatic processes. These techniques are also described in the following sections [78, TWG, 2005].

#### 17.7.3.1 Roller coating

##### Description

Application in a machine where rollers are used to transfer the liquid coating or ink from an inkpot onto the moving strip

### **Technical description**

Application takes place by rotating rubber or foam coated rollers; two side coating is also possible. The application weight can be adjusted by a variation of space between the rollers. If the workpiece and the roll are moving in the same direction, only layers of up to 12 µm can be applied, and only coating materials with a certain viscosity can be used. These problems do not occur in reverse coating processes where the roller rotates in the reverse direction to the movement of the workpiece.

A doctor blade (see Section 17.7.3.2) can also be fitted to adjust the thickness of ink/coating at the pressure or metering roller.

A particular use of reverse coating is the application of fillers to wood. In automated processes, the filling material is applied by rolling in reverse coaters and excess material is wiped off. After hardening, abrasion is necessary to obtain a smooth surface.

### **Achieved environmental benefits**

Depending on the workpiece and the conditions of processing, material efficiencies of about 90–100 % can be achieved.

### **Cross-media effects**

No data submitted.

### **Operational data**

No data submitted.

### **Applicability**

Roller coating is especially applicable for one- and two-component materials and polymerisation materials with high viscosity or 100 % solids content.

In the coating of metal packaging, roller coaters are commonly applied for the application of the external coating of cans. In three-piece can manufacturing, roller coaters are used exclusively for painting the sheets and also the 'side stripes' might also be applied by using rollers. In extruded aluminium tube manufacturing, roller coaters are used exclusively for applying the base coat.

This technique is widely applied in coil coating, see Section 6.4.3.1.

In the coating of wood and furniture, rolling is mainly applicable to flat workpieces, such as panels (plates) made of wood composites, but also slightly curved products such as wooden panels can be processed. For more curved surfaces, fillers are applied by hand equipment such as palette knives.

It is only used in marine industries for the coating of fishnets.

### **Economics**

A lightweight filling machine applied in the wood and furniture coating industry, with a working width of 1.3 metres and an installed electrical load of 5.5 kW cost EUR 55 000 in 2000. In another example, a foam roller with a working width of 1.3 metres and an electrical load of 3 kW cost about EUR 26 000. A machine applying two rollers (double system) with the same working width and an electrical load of 6 kW cost EUR 52 000. Both examples are from the year 2000.

### **Driving force for implementation**

No data submitted.

### **Example plants**

Coil coating and metal packaging plants  
See Economics.

**Reference literature**

[13, DFIU and IFARE, 2002] [78, TWG, 2005]

**17.7.3.2 Doctor blade (doctor knife) over roller**

**Description**

The coating is applied to the substrate through a gap between a blade and a roller. As the coating and substrate pass, the excess is scraped off. This process can be used for high viscosity coatings and very high coat weights, such as plastisols and rubber coatings

**Technical description**

The doctor blade (doctor knife) removes the excess ink/paint and allows only the required weight (thickness) to be transferred to the substrate.

This process relies on a coating being applied to the substrate which then passes through a ‘gap’ between a ‘knife’ and a support roller. As the coating and substrate pass through, the excess is scraped off.

**Achieved environmental benefits**

Low raw material consumption

**Environmental performance and operational data**

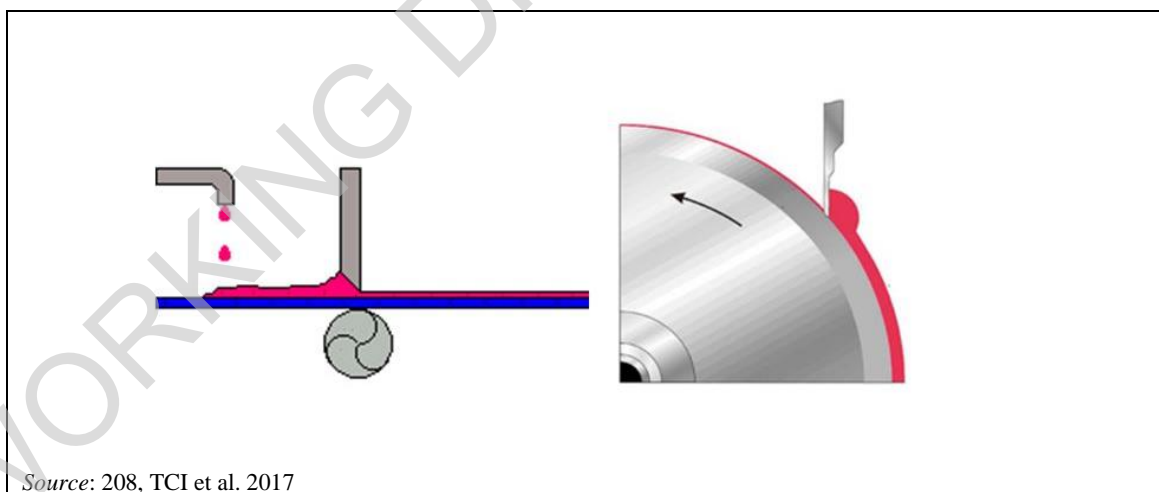
No information submitted

**Cross media effects**

No information submitted

**Technical considerations relevant for applicability**

This process can be used for high viscosity coatings and very high coat weights, such as plastisols and rubber coatings. There are various versions of this relatively simple process.



Source: 208, TCI et al. 2017

**Figure 17.9: Doctor blade (doctor knife)**

**Economics**

No information submitted

**Driving force for implementation**

No information submitted



**Example plants**

Widely applied in flexography and coating of textiles, foils and paper

**Reference literature**

[208, TCI et al, 2017]

**17.7.3.3 'Spray, squeegee and rinse' application**

See Section 6.4.3.1

**17.7.3.4 No rinse (dry in place) application**

See section 6.4.3.2

**17.7.3.5 Curtain coating (casting)****Description**

The paint or coating is held in a header trough and is discharged in a laminar film through which the workpieces are passed. Excess coating material is caught in a reservoir and pumped back into the sinkhead.

Mostly solvent-free lacquers based on polyester are applied but other types of coating materials can also be processed. Curtain coating can achieve a high quality in the equality of layers.

**Achieved environmental benefits**

Depending on the workpiece and the conditions of processing, material efficiencies of about 90–98 % can be achieved.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

In curtain coating, plain or almost plain workpieces are coated. According to the machine type, application weights from 40–500 g/m<sup>2</sup> can be processed.

Curtain coating is mainly used in the furniture industry for the coating of doors, wall units and other plates.

It is also widely used in coating printed circuit boards (more information can be found in the STM BREF [59, EIPPCB, 2005]).

**Economics**

A casting installation applied in the wood and furniture coating industry with a working width of 1.3 metres and an installed electrical load of 3 kW cost EUR 35 000 in 2000.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

## Reference literature

[13, DFIU and IFARE, 2002] [27, VITO, 2003] [59, EIPPCB, 2005]

## Conventional dipping

**Description:** The workpieces are either dipped manually or transported and dipped via automatic systems into a tank filled with the coating material. Dipping can be applied for all 1-component coating systems.

**Achieved environmental benefits:** The advantages of dipping include the very high efficiency of up to 100 %, complete coating of workpieces (outer surfaces as well as inner), cost effectiveness, high operational capacity and good possibilities for automation. However, an efficiency range of 80–90 % is also reported.

There is no spraying action to release solvent, although there will be evaporation from the tank.

**Cross-media effects:** Compared to spraying, thicker coating layers are achieved which consequently might result in a higher consumption of raw material. In the coating of agricultural and construction equipment, e.g. achieving a layer with a thickness of 50 µm applied via spray coating (HVLP) instead of a thickness of 85 µm when applying dipping, the material consumption is lower (even if the efficiency is lower due to spray application).

**Operational data:** Vents in the workpieces might be necessary to release trapped air.

Dipping in water-based paints might form foam. Water-based paints are only stable in a small range of pH and therefore very sensitive to contaminations that might be dragged over from the pretreatment processes (more information can be found in the STM BREF [59, EIPPCB, 2005]). A drying step after pretreatment, such as cleaning processes, is often not necessary when applying water-based paints.

**Applicability:** For the serial production of bulk articles that are coated in a single tone without colour changes, dipping is applicable. Application weights from 60–200 g/m<sup>2</sup> can be processed.

In the coating of agricultural and construction equipment, dipping is used for the application of 1-coat topcoats. Commonly, layers of 85 µm are achieved.

In the coating of wood and furniture, dipping is commonly applied for the coating of wooden window frames in serial production. However, in general this technique is limited in its application for the wood and furniture industry.

This technique is currently not applied in the coating of aircraft and in the coating of ships, and if applicable, only to newly constructed components. It is also not applied to the coating of trains.

In the marine industry, it is used for the coating of fishnets.

**Economics:** This is a cost effective technique.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002] [27, VITO, 2003] [59, EIPPCB, 2005]

### 17.7.3.6 Flooding

#### Description

The workpieces are transported via conveyor systems into a closed channel, which is then flooded with the paint material via injection tubes. The excess material is collected and reused.

**Achieved environmental benefits:** Depending on the workpiece and the conditions of processing, efficiencies of 95–99 % can be achieved.

#### Cross-media effects

In comparison to dip applications, the evaporation losses are higher.

#### Operational data

No data submitted.

#### Applicability

The process is especially suitable for large workpieces with a large surface area, such as for heating elements, for the painting of parts for truck chassis or agricultural machines and also for the application of cavity sealings in the automotive industry.

Application weights of 60–200 g/m<sup>2</sup> can be processed.

#### Economics

No data submitted.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

[13, DFIU and IFARE, 2002]

### 17.7.3.7 Vacuum coating

*ESVOC propose deletion;*

*TWG please provide updated information*

#### Description

The workpieces are transported via conveyor systems into a closed chamber where a vacuum is created. The products that are going to be painted are routed through this chamber at high speed. The paint is applied from four different sides.

#### Achieved environmental benefits

Depending on the workpiece and the conditions of processing, efficiencies of 80–100 % can be achieved.

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

Vacuum coating can be used in the painting of MDF panels, solid wood, veneer, profiles made out of paper composites, window panes, skirting boards and panels for walls and ceilings. Apart from water-based paints, vacuum coating has also been recently applied to UV curing paint on wood or wood composites. Vacuum coating is only applicable to wood that can withstand vacuum.

### Economics

In a real case scenario, changing from air-assisted airless spraying of water-based paints with infrared drying to vacuum coating, applying UV curing paints resulted in a yearly saving of EUR 262 000. Payback time was less than two years (reported in 2003). The result was the avoidance of VOC emissions (14 tonnes/yr), waste (which used to be 100 tonnes/yr) and the material efficiency of the UV curing paint was 100 %.

### Driving force for implementation

No data submitted.

### Example plants

No data submitted.

### Reference literature

[27, VITO, 2003, 38, TWG, 2004]

### **[Airless spraying]**

*[Proposed for deletion as a conventional technique]*

#### **Description**

Paint material is forced through a small nozzle at material pressures of 80–250 bar.

#### **Technical description**

The atomisation of paint material is carried out mechanically by using hydrostatic pressure. Paint material is forced through a small (<2 mm) hard metal nozzle at material pressures of 80–250 bar. The paint jet is then broken up by the forces of expansion and interaction of the paint jet with the stationary air outside the nozzle. The airless spraying technique can be fully automated or can be operated manually.

**Achieved environmental benefits:** The material efficiency of the airless spraying technique is about 5 % for lattice like workpieces and in the range of 40–75 % for workpieces with a larger surface area.

**Cross-media effects:** No data submitted.

**Operational data:** To obtain similar surface qualities, processing conditions have to be adjusted when compared to high pressure compressed air spraying. Fast colour changes are not possible due to the essential high pressure pumps.

The use of airless spraying gives a rough profile that needs sanding before further more refined coatings are applied.

**Applicability:** Airless spraying is used in the automotive industry. It is commonly used in the furniture industry and for the industrial coating of sizeable objects such as aircraft, ships or heavy machines. On trains, ground coat can be applied by airless spraying. On ships, almost all paint layers are commonly applied with airless spraying. It is cheap, fast and well known as it has been in use for many years. Also the dry film thickness can be well controlled. It can be used for both 1-component and 2-component paint.

**Economics:** Investment costs including a spray gun, a pump and other necessary equipment is in the range EUR 3600–7800. Additional costs are necessary for training the operators.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002] [11, InfoMil, 2003] [38, TWG, 2004]

### 17.7.3.8 Air-assisted airless spraying

#### Description

Shaping air is used to modify the spray cone of an airless spray gun.

The same conditions occur when using the airless technique as described in Section 0.

#### Achieved environmental benefits

The material efficiency for the air-assisted airless technique is about 35–70 %.

#### Cross-media effects

No data submitted.

#### Operational data

Air-assisted airless spraying typically performs better than airless spraying. With a good training of the operator, the same performance can be achieved as with conventional spraying, especially for primers.

#### Applicability

This technique is mainly applied for coating large pieces or surfaces. It is commonly applied in wood and furniture painting. The use of air-assisted airless spraying is becoming more common in yacht finishing.

#### Economics

Investment costs including a spray gun, a pump and other necessary equipment is in the range EUR 2 600–5 200 (see Reference literature, below). Additional costs are necessary for training the operators.

In one specific case, the initial costs for applying this technique were EUR 2 900 while savings of EUR 3 100 per month were made on the consumption of paint. In this particular case, the payback time was less than a month.

#### Driving force for implementation

No data submitted.

#### Example plants

See Economics.

#### Reference literature

[13, DFIU and IFARE, 2002] [27, VITO, 2003] [78, TWG, 2005]

### 17.7.3.9 Manual electrostatic guns [~~Electrostatic atomising processes~~]

*ESVOC propose deletion – modification proposed*

#### Description

Paint is atomised by air or pressure in an electrostatic field, and is transported along the electric flux lines.

#### Technical description

For this process, paint material is atomised by ~~via an electric field~~ air or pressure (airless). Paint material is transported to the workpiece along the ~~same~~ electric flux lines ~~electrical field that causes the atomisation~~.

There are three different options:

- Spraying gap, suitable for flat workpieces without depressions. The maximum material flowrate is 2–3 ml/min. The time required for colour changes is high (approximately 30 minutes). Depending on the workpiece and the conditions of processing, the efficiency is up to 99 %.
- Spraying bell, suitable for small parts and tubular structures with only small depressions. According to the size of the spraying bells, a maximum material flowrate of up to 250 ml/min is possible. Colour changes can be carried out within several minutes. The material efficiency is also very high (up to 95 % depending on the conditions of processing and the geometry of the workpiece).
- Spraying disc, also suitable for tubular structures and small parts with depressions. A maximum material flowrate of up to 800 ml/min is possible according to the size of the disc. Times for colour changes as well as the efficiency are comparable to spraying bells.

### **Achieved environmental benefits**

Depending on the workpiece and the conditions of processing, the efficiency is up to about 95 % ~~up to 100 %~~. Compared to conventional spraying, fewer residues are generated and spray booths are less polluted, so less cleaning agents are needed. Painting time is also reduced.

### **Environmental performance and operational information**

For wood, the moisture content of the wood needs to be at least 10 %.

### **Cross-media effects**

Energy consumption.

### **Technical considerations relevant to applicability**

Generally, in order to apply electrically assisted spray applications, the substrate will have to be conductive so it is not possible to recoat existing coatings (e.g. in ship repair and maintenance). This also limits the coatings and substrates that can use these techniques. A charge transfer additive may have to be added. Water-based materials cannot be processed with this technology, so processes with electrostatic atomisation are only utilised for specific applications. The advantage of such devices is the good reliability and the high effectiveness. The effect of the ‘Faraday cage’ makes it impossible for the paint particles to reach cavities. There may be problems with pinholing and poor appearance.

Automated electrostatic spray application is commonly applied in the coating of cars, trucks and commercial vehicles.

In wood and furniture painting, electrostatic spraying is sometimes used with chairs and window frames. It is usually combined with other spraying applications such as pneumatic, airless or air-assisted spraying.

This technique is not applied in the coating of ships and trains.

### **Economics**

An electrostatic system for spraying liquid paint including a spray gun, an eight litre container and associated equipment costs EUR 5 100–7 800.

### **Driving force for implementation**

No information provided.

### **Example plants**

No information provided.

**Reference literature**

[5, DFIU and IFARE, 2002] [26, CITEPA, 2003] [27, VITO, 2003] [38, TWG, 2004][183, ACEA 2017].

**17.7.3.10 Pneumatic atomisation with inert gases[the unicarb-system]****Description**

Pneumatic application with pressurised unreactive (inert) CO<sub>2</sub> gas.

**Technical description**

In this process, the air ~~organic compounds~~ are replaced by CO<sub>2</sub>, which is fed to the high viscous paint material. The paint CO<sub>2</sub> mix is processed at temperatures of 40–70 °C and with a pressure of approximately 100 bar. Atomisation is done via an airless spray application. Due to the fast evaporation of the CO<sub>2</sub>, a bell shaped spray sheet with a lower velocity of paint particles is used compared to regular airless spraying.

**Achieved environmental benefits**

The first practical experiences obtained in several sectors, mainly in the US, show significant reductions of material consumption and VOC emissions.

**Cross-media effects**

Energy is used for heating. Global warming effect of the CO<sub>2</sub> released, although the quantity may not be significant.

**Operational data**

The first practical experiences were obtained in several sectors, mainly in the US.

**Applicability**

Applicable in several sectors. CO<sub>2</sub> atomisation does not work with epoxy resins as the CO<sub>2</sub> reacts with the curing agent.

The substrate should be heat resistant as the paint/CO<sub>2</sub> mix is processed at temperatures of 40–70 °C. This temperature is sometimes too high for wood (risk of staining).

**Economics**

No data submitted.

**Driving force for implementation**

Workplace health and safety.

**Example plants**

No data submitted.

**Reference literature**

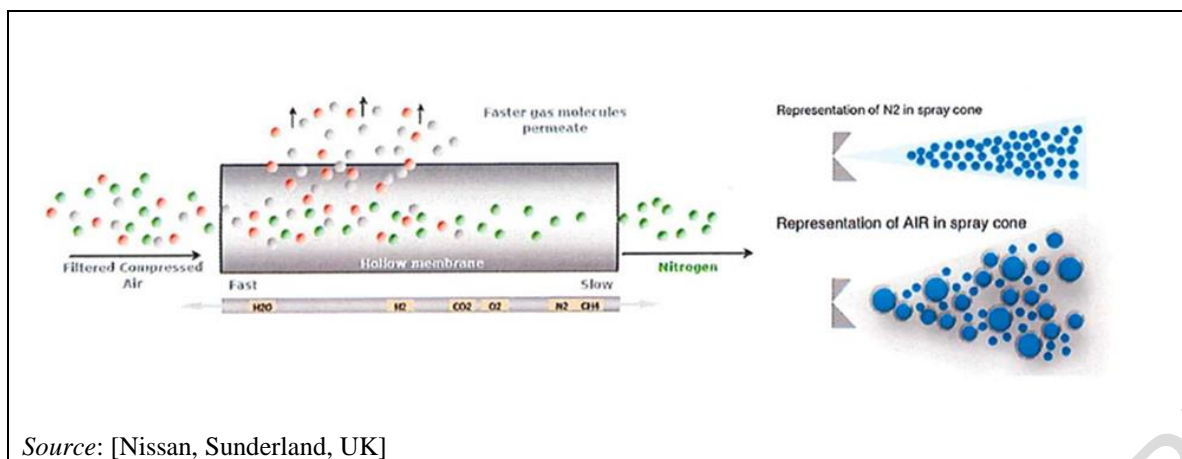
[13, DFIU and IFARE, 2002] [38, TWG, 2004] [95, CEI-BOIS, 2006]

**17.7.3.11 Pneumatic atomisation with Nitrogen****Description**

Pressured air used in pneumatic spray guns for atomising the paint is partially replaced by nitrogen.

**Technical description**

Nitrogen assisted spraying is a spray painting method that allows you to spray with nitrogen instead of normal compressed air. A standalone machine can produce nitrogen directly from the compressed air using a polymeric membrane ('molecular discriminator').



Source: [Nissan, Sunderland, UK]

**Figure 17.10:(a) Production of nitrogen using polymeric membrane and (b) comparison of spray cones**

The nitrogen-rich air can then be used for paint atomisation and shaping.

Nitrogen molecules are approximately twice as fast as air and have less turbulence. This is because with conventional air there is a mix of molecules which move erratically rather than the almost pure nitrogen which moves in unison, see Figure 17.10.

#### **Achieved environmental benefits**

Nitrogen-assisted spray painting technique results to higher paint transfer efficiency. It reduces the amount of paint over spray; this reduces the amount of paint used. By reducing the amount of paint used, particulate emissions and VOC emissions are reduced.

#### **Environmental performance and operational information**

The techniques provides many benefits:

- less overspray / improved transfer efficiency;
- improved pattern control;
- smaller nozzle size and therefore finer atomisation;
- improved temperature control;
- improved ionizing control.

#### **Cross-media effects**

No information provided.

#### **Technical considerations relevant to applicability**

No information provided.

#### **Economics**

No information provided.

#### **Driving force for implementation**

No information provided.

#### **Example plants**

Nissan Sunderland, UK.

#### **Reference literature**

[183, ACEA 2107] [191, EuroSidar 2017]



### 17.7.3.12 High-volume low-pressure spraying (HVLP) atomisation (high efficiency spray guns)

#### Description

Atomisation of paint in a spray nozzle by mixing paint with high volumes of air with a low pressure (maximum 1.7 bar). HVLP guns have a paint transfer efficiency of > 50 %.

#### Technical description

The atomisation of paint material is carried out mechanically by using compressed air. For atomisation, paint material and compressed air are introduced to a jet where the paint is atomised in a spray gun. The discharging air transports the paint particles onto the surface. With higher air pressure, more paint will be sprayed, but the overspray losses are also higher due to the distracted airflow. If the air pressure is too low, the result will be a poor surface quality. HVLP atomisation results in a smaller amount of atomised small paint particles compared to the conventional spraying techniques described in Section 0, because a reduced air pressure is applied.

The HVLP concept was developed in the 1980s with the main idea of achieving a 60 % transfer efficiency by limiting atomising pressure to 0.7 bar. This pressure, however, does not achieve the required quality of finish or the speed of application. New designs of air caps have been developed to give the required transfer efficiency as well as desired quality of finish and speed of application but working under higher atomising air pressure. The atomising pressure in these guns is higher than the pressure related to HVLP atomisation but still less than half of the pressure used in conventional air-atomising spray guns. Low pressure guns can be fed from any type of paint container, attached to gun, pressure fed tank or pump. The paint container can be on top of the gun or placed under the gun; the container on top can be used until completely empty.

#### Achieved environmental benefits

HVLP atomisation achieves a material utilisation in the range of 40–80 %. In comparison to high pressure compressed air spraying, material savings of up to 20 % are achievable if the paint container is on top of the spray gun.

#### Cross-media effects

No data submitted.

#### Operational data

Due to the generation of larger paint particles, the optical appearance can be different compared to conventional spraying. However, modern low pressure guns yield coatings of a quality equal to that achieved with high pressure guns with a similar workload. The work rate using HVLP atomisation can be slow and there is little dry film thickness control.

Application weights of up to 250 g/m<sup>2</sup> can be processed.

#### Applicability

HVLP atomisation can be applied to all surfaces. In wood and furniture painting, HVLP atomisation is applied for low viscous wood stains; however, also increasingly for other paint systems. This technique is also widely applied in the general automotive industry and, to a lesser extent, in the coating of trucks and commercial vehicles and the coating of agricultural and construction equipment. Since trains are coated manually, HVLP atomisation can be applied for the topcoats. It is also applied for the coating of plastic workpieces.

This technique is not commonly applied in the coating of ships (where HVLP atomisation is used in some topcoat applications and possibly for varnish) or aircraft.

#### Economics

HVLP spray guns cost about EUR 275–550, excluding the costs for adapting the compressor and the compressed air tubes to the higher flows. Costs for the training of personnel for about one to two days also need to be taken into account.

Payback time is often less than one year, depending on the amount of paint applied and current efficiencies achieved.

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

### **Reference literature**

[13, DFIU and IFARE, 2002] [27, VITO, 2003, 38, TWG, 2004] [78, TWG, 2005]

### **17.7.3.13 Electrostatically assisted high-speed rotating discs and bells**

#### **Description**

Atomisation by high-speed rotating discs or bells and shaping the spray jet with electrostatic fields

~~Electrostatically assisted high rotation discs and bells atomise the paint materials mechanically.~~

#### **Technical description**

As the atomisation is physical, electrical properties of the paint material are not relevant. Compared to electrostatic atomisation, these processes show a higher flexibility with regard to paint materials and material flows.

#### **Environmental performance and operational information**

Minimisation of material consumption and of waste.

Depending on the workpiece and the conditions of processing, efficiencies of up to 95 % can be achieved. Compared to conventional spraying, less overspray is generated and spray booths are less polluted so fewer cleaning agents are needed.

Depending on the workpiece and the conditions of processing, application efficiencies of up to 95 % can be achieved. In the automotive industry, efficiencies of up to 70 % can be achieved when internally charged electrostatic systems are used. Compared to conventional spraying, fewer leftovers are generated and spray booths are less polluted, so fewer cleaning agents are needed. Painting time is also reduced.

The charge can be loaded externally or internally; internal charge is more expensive but yields higher transfer efficiencies. If water-based paints are used, the paint must not be loaded electrostatically before leaving the application bell (externally charged). If special lacquers (metallic paints) are applied, a variance in the colour and the surface quality may occur.

#### **Cross-media effects**

None identified.

#### **Technical considerations relevant to applicability**

Typical applications are the painting of profiles and bicycle frames. This process is suitable for almost all paint materials including water-based paints. This technique can be used with automatic or manual applications.

Material flows of up to 1 000 ml/min can be achieved. A change of colour can be made within several seconds.

Due to material flows of up to 1 500 ml/min and a material efficiency of 95 %, the process is eligible for universal industrial painting operations.

Water-based paints can be processed. This technique can be used with automatic applications or can be operated manually.

Electrostatically assisted high rotation bells are widely used in the automotive industry, and increasingly for automotive parts.

In the coating of aircraft, electrostatically assisted spray application is commonly applied.

In the coating of trucks and commercial vehicles, electrostatically assisted spray application is commonly applied.

This technique is not applied in the coating of ships and trains.

### **Economics**

Internally charged processes typically cost between EUR 250 000 and EUR 1 600 000 depending on the size and amount of automation.

### **Driving force for implementation**

Painting time is also reduced.

### **Example plants**

Renault, France.

### **Reference literature**

[13, DFIU and IFARE, 2002] [68, ACEA, 2004] [78, TWG, 2005]

#### **17.7.3.14 Electrostatically assisted air or airless spraying ~~compressed air, airless and air-assisted spraying~~**

*ESVOC; Combine with 20.7.3.18*

*Includes 20.7.3.18 Application of powder coatings – electrostatically assisted spraying*

### **Description**

Shaping the spray jet of pneumatic or airless atomisation with an electrostatic field. Electrostatic paint guns have a transfer efficiency of > 60 %. Fixed electrostatic methods have a transfer efficiency of up to 75 %.

### **Technical description**

For electrostatically assisted compressed air, airless and, air-assisted spraying, the paint material atomisation is similar to regular compressed air spraying except for the airless technique. There, atomisation is realised via the hydrostatic pressure of the material. Additionally, the paint particles are electrostatically charged, however, this does not happen when applying water-based paints. According to the application conditions, the material flows for compressed air amount up to 1 000 ml/min. For airless or air-assisted airless techniques the material flow can be up to 3 000 ml/min.

~~Electrostatically assisted spraying of powder coatings is addressed in Section 0.~~

### **Achieved environmental benefits**

The material efficiency is about 85 %. In the painting of furniture and wood, efficiency levels in the range of 50–70 % are achievable. Compared to conventional spraying, fewer leftovers are generated and spray booths are less polluted so fewer cleaning agents are needed. Painting time is also reduced.

### **Cross-media effects**

No data submitted.

### **Operational data**

According to the implemented supply equipment (only one pump or one pump for each colour), the time needed for colour changes varies.

Complex geometries with depressions can be painted via compressed air spraying.

### **Applicability**

All the electrostatic techniques can be used for water-based and conventional materials. These techniques can be fully automated or can be operated manually. In the painting of furniture and wood, airless or air-assisted airless techniques are mainly used for high material consumption or high surface throughputs such as, for example, for the automated coating of furniture (workpieces with depressions), automated coating of window frames or manual coating of large workpieces.

In the automotive industry, pneumatic techniques only are used in some applications either manually or by using robots, e.g. for coating the interiors.

In the coating of aircraft, electrostatically assisted spray applications are commonly applied.

In the coating of trains, airless spraying systems can be used for applying ground coats; however, no information was submitted on electrostatically assisted spraying of trains.

In the coating of plastic workpieces, electrostatically assisted spray applications are commonly applied.

This technique is not commonly applied in the coating of ships, because in the open air there is too much air movement and in other poorly ventilated areas there is a potential for explosion. However, it is used in some yards in the Netherlands.

### **Economics**

No data submitted.

### **Driving force for implementation**

No data submitted.

### **Example plants**

#141, See also Applicability, above.

### **Reference literature**

[13, DFIU and IFARE, 2002] [78, TWG, 2005]

### **[In-mould painting]**

*[ESVOC proposed deletion]*

**Description:** The surface coating is applied to a mould and the material to be coated is applied to the coating within or on the mould.

~~This technique is applied to steering wheels which are made from 2-component PUR materials that are poured and cured in a mould. The production and painting of the wheel is done at the same time. For the coating of the steering wheel, a release agent is applied to the heated mould and the coating material is sprayed onto the release agent. After a short evaporation time, the PUR material for the steering wheel is poured into the mould and the mould is closed. The foaming process of the PUR starts and at the same time the coating material adheres to the PUR.~~

**Achieved environmental benefits:** The proportion of overspray produced and, therefore, the material loss is about 20 % of the input.

**Cross-media effects:** No data submitted.

**Operational data:** Up to now only solvent based coating materials have been applied as water based in mould coating systems are currently in a testing phase.

**Applicability:** This technique can be used in the construction of plastic resin components (e.g. boat hulls and for the production of steering wheels).

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DEIU and IFARE, 2002]

### **[Conventional high and low pressure spraying]**

*Conventional techniques have been deleted if they can no longer be considered BAT.*

*This does not prohibit their use, or mean they are no longer valid. It means they are not BAT to include in a 'basket of measures' to reduce consumptions or emissions*

#### **Description:**

Atomisation of paint in a spray nozzle by mixing paint with pressurised (compressed) air

#### **Technical description**

The atomisation of paint material is carried out mechanically by using compressed air. In a conventional spray gun, paint material and compressed air are introduced to a jet where the paint is atomised. The discharging air transports the paint particles onto the surface. With higher air pressure, more paint will be sprayed, but the overspray losses are also higher. If the air pressure is too low, the result will be a poor surface quality.

**Achieved environmental benefits:** No data submitted.

**Cross-media effects:** Highest consumption of resources compared to the other application techniques and this technique is associated with higher VOC emissions.

**Operational data:** All surfaces can be coated by this method and high surface qualities can be achieved.

**Applicability:** The efficiency varies from about 5 % for lattice like workpieces to about 30–60 % for workpieces with a larger surface area. Efficiencies in the automotive industry are reported to be in the range of 18–35 % where sprayed manually without electrostatic assistance.

Conventional spraying is applicable to all surfaces, and is, for example, applied for the coating of vehicles, furniture and machines. Application weights of up to 250 g/m<sup>2</sup> can be processed.

In the automotive industry, often an application procedure with a conventional air spray gun is necessary after the electrostatic application of the base coat, in order to achieve the desired optical quality (metallic and pearl effects).

It is commonly applied in the coating of agricultural and construction equipment, coating of trains, coating of metal packaging (for the interior of DWI cans) and for wood and furniture painting.

Conventional spray is the major choice for quality yacht topcoat application as it achieves a high gloss finish.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [13, DFIU and IFARE, 2002] [78, TWG, 2005]

### 17.7.3.15 Hot spraying

*ESVOC propose deletion. Revised version supplied*

#### Description

Pneumatic atomisation with hot air or heated paint, used for application of high-viscosity paint.

#### Technical description

The atomisation of paint material can be carried out by using compressed air or by using hot airless spraying. The paint material and/or the compressed air are heated, the viscosity of the paint system is therefore lowered and the amount of thinners can be reduced which results in lower VOC emissions. The heating (to 60–70 °C) of the paint material is carried out in the spray gun container or via heated pipes for compressed air and the paint material. Flow heaters for the heating of the compressed air are utilised for paint materials that otherwise would already start to react at these temperatures. This can be used with water-based, solvent-based or solvent-free two-component epoxy systems.

#### Achieved environmental benefits

The reduced amount of thinners results in lower or even no VOC emissions. Compared to conventional spraying, the number of layers can be reduced.

Material efficiencies of 40–60 % can be achieved. An efficiency improvement of up to 10 % can be achieved when compared to conventional spraying.

#### Environmental performance and operational information

Commonly used for paints with a high solids content, but is also applicable for hot-wax spraying. It can be operated under the following conditions:

- 60–200 bar when spraying paints containing high solvent or water;
- 200–400 bar when spraying paints containing thick, high solids;
- two-component paints if online mixing is applied (see Section 20.6.3.1).

With the increased temperature, higher layer thicknesses can be applied without the formation of edge runners. However, the following restrictions also apply:

- pot life very short;
- equipment is expensive;
- single integer volume mix ratio needed;
- high-solids/solvent-free epoxy paint is used;
- operator needs training because the equipment is difficult to use.

**Cross-media effects**

Energy is used for heating.

**Technical considerations relevant to applicability**

The necessary reheating after colour changes makes this technique unsuitable for processes with frequent colour changes.

Hot spraying is sometimes used in the painting of furniture, e.g. on cupboards. The technique might be applicable for the coating of ships and yachts.

**Economics**

Because thicker layers are applied, costs for labour are lower compared to conventional coatings and their application methods.

**Driving force for implementation**

No information provided.

**Example plants**

No information provided.

**Reference literature**

[5, DFIU and IFARE, 2002] [11, InfoMil, 2003] [38, TWG, 2004][183, ACEA 2017]

~~**[Electrostatically assisted high-rotation bells]**~~

*Combined with 17.7.3.13*

~~**Application of powder coatings – electrostatically assisted spraying**~~

*Combined with 17.7.3.14" Electrostatically assisted compressed air, airless and air-assisted spraying"*

~~**Description:** The powder particles are electrostatically charged and sprayed onto the ground workpiece using compressed air.~~

~~**Achieved environmental benefits:** Material efficiencies in the range of 80 – 95 % are achieved.~~

~~Spray booths and application tools can be cleaned by vacuum cleaning or by blowing with compressed air. In this way, resources are saved and solvent emissions are avoided.~~

~~**Cross-media effects:** Compressed air requires energy use.~~

~~**Operational data:** Electrical conductivity has to be considered.~~

~~**Applicability:** Generally applied.~~

~~Used in a small number of coil coating lines, but has serious limitations on speed and film thickness, see Section 6.4.2.5. In the painting of furniture and wood, it is commonly applied when powder coating is used.~~

~~**Economics:** No data submitted.~~

~~**Driving forces for implementation:** No data submitted.~~

~~**Example plants:** No data submitted.~~

~~**Reference literature:** [13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]~~

**[Application of powder coatings – powder sintering]**

*[ESVOC proposes deletion]*

**Techniques to manage overspray**

*Merged with Section 17.10.4 Dust abatement*

**Water treatment techniques to reduce waste water and wastes and for treatment of waste water**

*This section has been removed to simplify the approach to techniques for water-based processes. Techniques largely related to water use and recycling have been moved to/combined with techniques in Section 17.4. Techniques related to waste water treatment have been moved to Section 17.11.*

*Brief descriptions are provided to assist with e.g. discussions on emissions to water. Detailed discussion has been removed according to KOM conclusions where these techniques are fully described in the STM BREF.*

*The general purpose of these measures described in the following sections is to avoid material losses and emissions to water, reduce water usage and consequently reduce the need for waste water treatment. To do this, several well known unit operations for phase and material separation are applied. Most of these These techniques are described in full detail in the STM BREF [59, EIPPCB, 2005].*

**Multiple (cascade) rinsing**

*Moved to Section 17.4.1.3*

**Use of ion exchangers**

*Moved to Section 17.4.1.5*

**Membrane filtration**

*Now includes in Section 17.11.8*

**Bath desludging**

*These techniques are fully described in the STM BREF*

**Process solution filtration**

*These techniques are fully described in the STM BREF*

**Continuous discharge of paint sludge**

*Merged with section 17.12.8*

**Decantation system**

*Merged with section 17.12.8*

*Decantation systems in wet separation spray booths increase the service life of the water. This technique is commonly applied in:*

- the automotive industry*
- coating of trucks and commercial vehicles*
- coating of trains.*

*[13, DFIU and IFARE, 2002]*



## 17.8 Drying and/or curing techniques

Drying is one of the most energy-consuming processes. Drying is used for:

- drying of paint;
- drying of ink;
- drying of adhesives;
- drying of retained water or other liquids from pretreatment or rinsing zones;
- gelling and solidification of adhesives or underbody protection materials;
- pretreatment of workpieces (against cold surfaces or trapped air in the lacquer finishing of wood).

Radiation curing is based on resins and reactive diluents (monomers) which react together on exposure to, e.g. ultraviolet light (UV) or high energy electron beams (EB). The resins are generally polyesters, polyurethanes or epoxies, with acrylate or methacrylate functionality, though other coating chemistries may also be used. The formulations are liquid, but are solvent-free and curing can be very fast, just a few seconds, generally at ambient or slightly raised temperatures.

### **Drying by convection]**

*Proposed for deletion as a conventional technique*

*TWG please confirm if this is still a BAT candidate*

#### **Description**

~~Drying of a wet surface with hot air, where the necessary heat is conveyed primarily by convection.~~

#### **Technical description**

~~Heated air is circulated in the dryer or oven to transport heat to the workpiece. The air is in direct contact with the object or surface to be dried. The drying time depends on the object or substrate, the type of coating and the coating thickness, and varies between a few seconds to a full hour.~~

~~For the drying of water based coatings or a pre drying step of wet on wet layer constructions, dehumidified air is use, with convection dryers with an additional dehumidification step. Due to the uptake of water, the drying times can be significantly reduced.~~

~~The dryers are built as flat line dryers, nozzle dryers, tray systems or tower dryers. The energy demand heavily depends on the heat losses of the dryer.~~

#### **Environmental performance and operational information**

##### **Achieved environmental benefits**

~~No data submitted.~~

##### **Operational data**

##### **Cross-media effects**

~~No data submitted.~~

##### **Technical considerations relevant to applicability**

~~In dryers used for fast moving, continuous substrates such as paper and plastic foil webs or continuous streams of small objects such as beverage cans, the drying time is measured in seconds and the length of the dryer in centimetres. Not the temperature, but the airflow is most important. Energy can be saved by recirculating air, but this is limited by the need to avoid fire~~

or explosion and to avoid odour in the end product. Dryers are heated by flame, steam, thermal oil or electricity.

Applicable to all heatsetting coating or printing materials, either solvent based or solvent free. There is no limitation on layer thickness or pigmentation. The geometry of the coated substrate is not relevant; however, it should be heat resistant.

Convection dryers can be used for drying layers of water based paints, for a pre drying step or for wet on wet layer constructions. They are commonly applied in the coating of plastic bumpers, in coil coating processes, in wood and furniture painting, in the manufacture of adhesive tapes and in the automotive industry.

Convection dryers are commonly applied in the manufacturing of abrasive.

#### **Economics**

The costs for drying mount up to 15–20 % of the total energy costs of the painting line in the automotive industry.

A 10 minute convection dryer applied in the wood and furniture coating industry with an installed electrical load of 30 kW and an air output of 1500 m<sup>3</sup>/h cost EUR 60 000 in 2000. The electrical control and conveying unit is excluded.

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

No data submitted.

#### **Reference literature**

[13, DFIU and IFARE, 2002] [27, VITO, 2003] [12, UBA Germany, 2002] [38, TWG, 2004] [78, TWG, 2005]

### **17.8.1 Inert gas convection drying/curing**

#### **Description**

The inert gas is heated with gas or steam via heat exchangers or fuel oil. By applying inert gas instead of normal air, solvent loads of > 1 200 g/m<sup>3</sup> nitrogen are possible.

#### **Achieved environmental benefits**

Inert gas can contain much more solvent than normal air. For an inert gas drying process, for example, a gas volume of 2 000 m<sup>3</sup> is circulated for a solvent amount of 400 kg/h. Air drying would need up to 10 times as much volume to meet 40 % of the LEL value.

Energy is saved and waste gas treatment systems can be designed for smaller capacities compared to the use of normal air. The flammability is reduced.

#### **Cross-media effects**

No data submitted.

#### **Operational data**

Where inert gas is used for drying, condensation may be used as a technique for recovering solvents (see Section 17.10.6.1).

#### **Applicability**

Applicable to new and existing plants and installations. However, retrofitting might be difficult.

This technique is commonly applied as a pre-drying step in the manufacturing of adhesive tapes.

The technique is not applicable where dryers need to be opened regularly. Opening the dryer needs purging, i.e. replacing air by the inert gas. This is costly and takes time. This is the reason why it is not applied in industries where job changes are a daily occurrence such as all printing processes, e.g. flexible packaging.

It also is not applied in the manufacturing of abrasives, in coil coating, in the automotive industry, or in the coating of wood or furniture.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[14, DFIU and IFARE, 2002] [38, TWG, 2004] [95, CEI-BOIS, 2006]

## 17.8.2 Induction drying/curing

**Description**

Online thermal curing or drying by electromagnetic inductors that generate heat inside the metallic workpiece with the oscillating current induced by the oven.

**Technical description**

Electromagnetic coils mounted close to the painted coil induce oscillating currents within the metal that can be tuned to generate heating rates of hundreds of degrees per second.

**Environmental performance and operational information**

Electrical heating is very controllable and efficient with no local emissions.

**Cross-media effects**

Use of electricity to replace gas and subsequent translocation of emissions to generating plants.

**Technical considerations relevant to applicability**

For existing situations, there is a necessity to redesign the waste gas treatment unit because the heating times are much shorter compared to conventional dryers.

This technology is routinely used for metal tempering and annealing, but is also appropriate for rapid paint curing. Applied if the substrate or object to be dried conducts electricity. It might be applicable as a replacement or supplement to existing gas fired ovens. The potentially very high electricity demand may limit the applicability.

In the printing of metal packaging, it is applicable to all heatset coating or printing materials and on ferromagnetic substrates. However, coating formulations may need fine-tuning for different heating rates. There may be some limitations on the paint film thickness achievable with the very fast heating rates.

Induction is mainly used in special applications such as the hardening of structural bonding (adhesives) in the automotive industry. Used in a few lines in coil coating.

Because it requires a metal substrate, it is not applied in printing, the manufacturing of abrasive, the manufacturing of adhesive tape or the coating of wood or furniture. It is also not applied in the winding wire industry.

**Economics**

Only economically viable for new installations or when an oven requires replacing.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [22, ECCA, 2004] [38, TWG, 2004] [95, CEI-BOIS, 2006]

**17.8.3 Microwave and HF drying/curing [Radiation]**

*ESVOC Important*

**Description**

Drying or curing using electromagnetic microwaves.

**Technical description**

In this process, the wet paint layer is heated via electromagnetic microwaves. The two available techniques are microwave drying and high frequency drying (HF). Due to the impact of these electromagnetic waves, the dipoles are oscillated and, thus, the electromagnetic energy is transferred into heat energy. In this way, the contained water is evaporated rapidly and needs to be extracted.

HF dryers consist of a high frequency generator, the transmission unit, collector electrodes and the appropriate flashing-off zone for removal of the evaporated water. Alternatively, the wet paint layer is heated via electromagnetic microwaves. Evaporation and drying takes place from the inside of the paint layer to its outside. The heating is homogenous.

**Operational data**

No data submitted.

**Environmental performance and operational information**

**Achieved environmental benefits**

No data submitted.

**Cross-media effects**

No data submitted.

**Technical considerations relevant to applicability**

Electromagnetic wave dryers are exclusively applicable to water-based coatings and inks, and non-metallic substrates.

HF dryers are commonly applied in the manufacturing of abrasives, but are not applied in the manufacturing of adhesive tapes or in the winding wire industry.

Microwave drying is applied for the coating of wood, for workpieces prior to assembly and for pieces with small dimensions as large products need a large MW oven with higher energy costs. Its use in practice is doubtful. It is not applied in the manufacturing of abrasives, and in the manufacturing of adhesive tape.

**Economics**

A two-minute microwave dryer applied in the coating of wood and furniture industry, with an installed electrical load of 60 kW and an air output of 1 500 m<sup>3</sup>/h cost EUR 75 000 in 2000. Electrical control and conveying units are excluded.

A two-minute HF dryer applied in the coating of wood and furniture industry, with an installed electrical load of 120 kW and an air output of 1 500 m<sup>3</sup>/h cost EUR 150 000 in 2000. Electrical control and conveying units are excluded.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005] [95, CEI-BOIS, 2006]

**17.8.3.1 Infrared radiation drying/curing****Description**

Drying of paints with infrared radiation

**Technical description**

For infrared radiation drying/curing, the workpiece is heated via absorption of infrared radiation. The drying process starts from the inside to the surface. The intensity of the infrared radiation depends on the wavelength range and therefore of the temperature of the radiator. The absorption of the rays depends on the surface smoothness, the colour or lightness and its chemical composition.

**Environmental performance and operational information**

Lower energy demand compared to dryers applying circulated air.

It is a fast heating technique (1–5 seconds in the case of NIR medium or long wave, but IR may take longer) and, when the temperature of the substrate during paint drying/curing is low, it requires only short cooling times. The solvent composition needs to be adjusted to the energy of the radiation.

There is a risk of the formation of shades on edges and in niches.

Different radiators are available, according to the wavelength used. Flow path or programme controlled installations are applied according to drying and surface quality conditions.

**Cross-media effects**

Due to the radiant heat from the dryers, solvents are evaporated as for conventional heating processes.

**Technical considerations relevant to applicability**

There is no limitation of layer thickness, except where very fast cure times are required (e.g. where the substrate is moving rapidly, as in coil coating).

The geometry of the coated or printed substrate is not relevant. However, it should be heat resistant. In some cases, the temperature can be too high for wood, where there are risks of staining and burning.

Infrared curing is used on a small number of coil coating lines. For existing situations in coil coating, there is a need to redesign the waste gas treatment unit because the heating times are much shorter compared to conventional dryers.

The technique is commonly applied in the automotive industry for the pre-drying of topcoats that are applied by the wet-on-wet technique. It is also increasingly used in adhesive tape manufacturing.

It is not applied in the manufacturing of abrasives.

In the printing industry, it is no longer used due to improved inks. The disadvantages of using infrared radiation curing were the heat produced in the pile of the printed sheets and the blocking (i.e. the printed image reproduces itself on the back of the sheet above).

### **Economics**

Investment costs are relatively low; however, retrofitting existing dryers can be costly. In the coil coating industry, this technique is only economically viable for new installations or when an oven requires replacing.

### **Driving force for implementation**

No data submitted. Low energy demand and speed of drying.

### **Example plants**

Opel Eisenach GmbH, Germany.

### **Reference literature**

[13, DFIU and IFARE, 2002] [22, ECCA, 2004] [38, TWG, 2004] [78, TWG, 2005] [95, CEI-BOIS, 2006]

## **17.8.4 Combined convection and IR radiation drying/curing (Thermal reactor)**

### **Description**

Drying of a wet surface with a combination of circulating hot air (convection) and an infrared radiator.

### **Technical description**

A thermal reactor is a radiator that emits infrared radiation as well as convection heat. The infrared radiation is generated by combustion of natural gas or propane TWG please confirm

### **Environmental performance and operational information**

Lower energy demand compared to dryers applying only circulated air.

Depending on the paint system and kind of production, the total drying time is in the range of 6 to 10 minutes.

### **Cross-media effects**

No data submitted.

### **Technical considerations relevant to applicability**

Applicable to all heatset coating or printing materials, either solvent-based or solvent-free, and powder coatings. Thermal reactors are also suitable for water-based paint systems.

The geometry of the coated or printed substrate is not relevant; however, it should be heat resistant.

Although some costs are given below, the technique is not known to be applied commercially in the coating of wood. There is a risk of staining and burning of the wood if the temperatures are too high.

It is not applied in the manufacturing of abrasives, in the manufacturing of adhesive tapes, in coil coating or in the automotive industry.

#### **Economics**

A thermal reactor with a six minute drying time for the coating of wood and furniture industry, with an installed electrical load of 10 kW, an air output of 2000 m<sup>3</sup>/h heated with natural gas, cost EUR 95000 in 2000. Electrical control and conveying units are excluded.

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

No data submitted.

#### **Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [95, CEI-BOIS, 2006]

### **17.8.5 Radiation curing processes**

Radiation curing is applied based on resins and reactive diluents (monomers) which react together on exposure to radiation (infrared radiation (IR), near-infrared radiation (NIR), ultraviolet (UV)), or high-energy electron beams (EB).

**Description:** Radiation curing is based on resins and reactive diluents (monomers) which react together on exposure to, e.g. ultraviolet light (UV) or high energy electron beams (EB). The resins are generally polyesters, polyurethanes or epoxies, with acrylate or methacrylate functionality, though other coating chemistries may also be used. The formulations are liquid, but are solvent free and curing can be very fast, just a few seconds, generally at ambient or slightly raised temperatures.

Sections **Error! Reference source not found.**, 17.8.5.1, 17.8.5.2 and 17.8.5.3 describe different types of radiation curing techniques in detail.

**Achieved environmental benefits:** A complete elimination of solvent use in the coating system. There are normally no significant emissions during curing and the cured coatings no longer contain volatile components. There is improved energy efficiency along with minimal gas consumption as high temperature ovens and exhaust incineration may no longer be needed.

**Cross-media effects:** There may be some potential for low level emission of VOCs as reactive organic monomers are used in the formulations.

**Operational data:** No data submitted.

**Applicability:** Radiation cured coatings have become well established in the wood coating and printing industries for the coating of flat pieces and sheets, but so far they have not been so successful in coatings for metal. Coil coating places very great demands on the coating system, especially in adhesion, flexibility, and durability. There have been considerable development efforts from coil coaters and coating suppliers to meet these demands, but so far there is no completely successful application of radiation cured coil coatings, see Section 19.14.2.

**Economics:** No data submitted.

**Driving force for implementation:** Elimination of solvents, and energy efficiency.

**Example plants:** No data submitted.

**Reference literature:** [38, TWG, 2004] [95, CEI BOIS, 2006].

### 17.8.5.1 Near-infrared radiation (NIR) curing

#### Description

Thermal curing of paints with infrared light of very short wavelength.

#### Technical description

#### Environmental performance and operational information

##### Achieved environmental benefits

No data submitted. *TWG please provide more information on solvent emissions and energy use.*

##### Environmental performance and operational information

NIR emitters operate at very high temperatures, producing very short wavelength infrared radiation at very high power density. Absorption of the specific wavelength by the coating and short dwell times can reduce the heating of the substrate.

##### Cross-media effects

High demands for electrical power. NIR requires a reliable high power electrical supply.

##### Technical considerations relevant to applicability

Due to very short (1–5 seconds) curing times, this technique is very suitable for heat sensitive materials such as wood and plastic. Powder coatings are commonly cured by applying NIR curing as well as water-based paints on wood. For the coating of wood, the NIR technique achieves the shortest drying and cycle times.

It is not applied in the manufacturing of abrasives, in the manufacturing of adhesive tapes, in the winding wire industry or in the automotive industry.

NIR curing is starting to be used in coil coating for the fast curing of thin coatings and in powder coatings. Its extension into general processing lines will depend on further proving trials.

##### Economics

No data submitted.

##### Driving force for implementation

Shorter more compact ovens, high speed, controllable power.

##### Example plants

No data submitted.

##### Reference literature

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]



### 17.8.5.2 Ultraviolet (UV) curing

#### Description

'Cold' crosslinking of appropriate paints with UV light (the paints need to be UV-curable).

#### Technical description

The electrical discharge in gases is used as a radiator for UV curing. Most commonly, mercury vapour lamps are used for this purpose. The radiation starts a chemical cross-linking within the paint or ink layer. UV curing requires the presence of a photo-initiator.

#### Achieved environmental benefits

UV cured systems use less or no solvent. Energy consumption is low.

#### Environmental performance and operational information

Wooden or plastic substrates can show a yellowing and may become brittle. This technique requires little floor space and curing occurs within a few seconds (high speed).

#### Cross-media effects

Ozone emissions occur and the ozone is commonly extracted and routed to an ozone eliminator with catalysts or to a thermal oxidiser. Mercury vapour lamps are used, which contain ~~small amounts of mercury and can be~~ must be disposed of through suitable waste treatment facilities.

#### Technical considerations relevant to applicability

Applicable to new and existing installations.

Applicable to unsaturated polyesters, polyacrylates, epoxy resins, etc. Especially applicable to clear coats and glazes up to high layer thicknesses. For pigmented coatings, UV curing is only applicable for small layer thicknesses. Also UV curing inks are dried via UV curing.

The coated or printed substrates should be resistant to UV curing and preferably flat or two dimensional. The curing of powder coated three-dimensional wooden or plastic parts is more complicated, however, well performing drying systems are available.

UV radiation is widely applied to substrates of paper and cardboard. For example, it is applied for the drying of painted furniture, where flat panels can be coated separately and coating is done before assembling the piece of furniture. It is also increasingly applied in the production of adhesive tapes.

In coil coating, the technique is currently under evaluation (see also Section 19.14.2).

It is not applied in the manufacturing of abrasives or in the automotive industry.

#### Economics

Compared to conventional dryers, energy costs can be reduced by up to 70 %. Compared to a conventional gas-fuelled oven (including ventilator) for water-based paints, the energy costs are reduced by 40–50 %. In printing, the energy consumption may be as high as with conventional drying. Energy utilisation is reduced by 50 % using flash cure systems, where the lamp only operates when the actual substrate is underneath the lamp. This has economic benefits, for instance, when non-web printing is taking place.

~~Print run speeds of 3–4 times faster are achievable with UV cured systems.~~

~~A commonly used UV curing installation with a width of 25 cm costs about EUR 6 600 (only likely to be used in label printing, which, as a standalone activity, is outside the scope of this document). The trend is that prices are declining. The operational costs of a unit with 12 lamps of 5.6 kW each, were about EUR 5/h on energy (Flanders, 2003). However, a UV curing installation of 25 cm is not generally representative for other printing processes.~~

For example, a compact (one man) UV paint application plant including a UV curing zone applied in the wood and furniture coating industry cost roughly EUR 40 000 in 2000.

There are financial benefits from the faster curing/drying time and the faster production speeds achieved.

The payback time is estimated to be two to three years. This is also taking into account that for applying UV curing paint systems less man hours are needed.

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

### **Reference literature**

[13, DFIU and IFARE, 2002] [27, VITO, 2003] [38, TWG, 2004] [78, TWG, 2005] [197, FPE, 2017]

### **17.8.5.3 Electron beam curing (EB)**

#### **Description**

'Cold' cross-linking of EB-curable paints with high velocity electrons.

#### **Technical description**

EB curing is initialised by an electron beam emitted from a hot cathode tube. Polymerisation and, thus, hardening of the paint is caused by the impact of electrons onto the monomers. A high level of automation is possible. Electrons are accelerated to a high velocity penetrating the coating substance and curing it in a very short time.

#### **Achieved environmental benefits**

UV cured systems use less or no solvent. *TWG please provide more information on energy consumption*

#### **Environmental performance and operational information**

There is a risk of the substrate becoming brittle and of discoloration.

Very small floor space is required.

Radiation imposes a risk to the workers. The workers have to be shielded from the electron beam by lead plates or concrete walls

#### **Cross-media effects**

No information provided.

#### **Technical considerations relevant to applicability**

*TWG please update with fresh information on applicability*

Applicable to unsaturated polyesters, polyacrylates, polyurethanes, epoxy resins, etc. There is no limit to layer thickness or pigmentation.

All geometries are suitable for substrates transparent to EB radiation (especially paper, wood or foils); for metals, EB is limited to flat substrates. Because of high investment costs, this technique is currently only applied to large surface throughputs.

EB curing is increasingly applied in the production of adhesive tapes.

In the coil coating industry, EB may be considered as an emerging technology.

It is not applied in the manufacturing of abrasives, in coil coating, or in the automotive industry.

**Economics**

EB curing has higher investment costs than conventional dryers. However, the energy consumption of EB curing can be very much lower.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005].

WORKING DRAFT IN PROGRESS

## 17.9 Cleaning techniques

[97, TWG, 2006, 104, Tempany, 2006, 108, ESVCCG, 2006]

### 17.9.1 Optimisation of cleaning [~~General principles for cleaning~~]

#### Description

Minimise the need to clean and select cleaning methods that:

- are compatible with the surfaces to be cleaned and contamination type;
- reduce consumption of solvent-based cleaning agents, waste generation and emissions.

#### Environmental performance and operational information:

Selection of the correct cleaning system can reduce solvent emissions and/or the formation of tropospheric ozone.

When selecting the cleaning techniques to be used, the following issues need to be considered.

#### 1. Type of cleaning:

- Process equipment cleaning. In all activities, the process equipment will be cleaned. This is of two types:
  - operational or interim cleaning. Cleaning of the application system is necessary at regular intervals, e.g.
    - for colour change and quality reasons. ~~e.g. for spraying cars, after five to ten vehicles and at each colour change;~~
    - cleaning of spray booths is necessary at regular intervals;
    - between printing jobs;
  - maintenance, periodic or in-depth cleaning. It is periodically necessary to clean application equipment thoroughly to remove accumulated deposits and clean parts of equipment that are more difficult to clean quickly. This usually requires some disassembly.

The type of technique used will depend on whether the equipment is cleaned in situ, or dismantled completely or in part

- Substrate or workpiece cleaning. For some activities, such as painting and varnishing, cleaning of the substrate or workpieces to remove grease, dirt, etc. is essential prior to coating. In some activities, such as printing, it is not necessary.

#### 2. Type of contamination:

- For process equipment:
  - Non-persistent contamination. The contamination is fresh, e.g. it is non-drying, it still has some of the original solvent present, or its coating reaction is not complete. This type of contamination is easy to remove, e.g. physically by hand (see Section 17.9.4), with the original or similar solvent used in the coating, with low volatility solvents (depending on the need to dry the components, see Sections 0 to 0), in washing machines (see Section 17.9.7), etc.
  - Persistent contamination. This may be from dried solvent-based products, UV or other radiation cured products, waterborne, or reactive (two-component) products, etc. Cleaning by hand with volatile solvents is not effective. The parts may be cleaned, for example:
    - in a washing machine (repeatedly if necessary), (see Section 17.9.7);
    - with powerful low volatility solvents (see Section 17.9.5);
    - high pressure water after using powerful solvents, or with an abrasive added (see Section 17.9.9);
    - ultrasonic cleaning (see Section 17.9.10);
    - dry ice blasting (see Section 17.9.11).

- For substrates and workpieces, contamination depends on the previous processes, and may include corrosion from storage, press oils, dirt and debris from cutting, shaping and grinding, finger marks from handling, etc. These and the options for cleaning are discussed in the STM BREF. In this sector, the parts are usually hand cleaned with wipes or rags (see Section 17.9.4) or in water-based detergent systems for high throughputs (see Section 17.9.6). Solvents can be used in washing machines for smaller components (see Section 17.9.7). Ultrasonic or dry ice techniques can also be used (see Sections 17.9.10 and 17.9.11).

3. Choice of technique and/or solvent. The technique and/or the solvent used should:

- be capable of achieving the cleanliness required in the process;
- be compatible with the parts being cleaned (whether they are substrates, workpieces or equipment parts);
- be compatible with the process, and the surface treatments; for example, in the printing of flexible packaging the system has to be dry of all solvents before adding new inks. In other activities, the cleaning systems can be compatible with the process and drying may not be necessary;
- reduce the emission of solvents and/or minimise the formation of tropospheric ozone (see Section 17.6.2);
- take into account the time available. In some cases, the time available for cleaning is limited; in other cases, cleaning systems that take more time can be used.

In some processes, disassembly of the equipment and some hand cleaning is inevitable for maintenance cleaning.

For operational cleaning, automated systems may be used.

There are overlaps between the techniques discussed in this section and with those techniques discussed in Section 17.7.2(Substitution). The factors discussed here are summarised in Table 17.5, with the possible techniques from the two sections. Techniques may also be combined and/or repeated to achieve the necessary cleanliness.

**Table 17.5: Examples of applicability of cleaning techniques and options**

Section	Cleaning techniques Technique	Process equipment		Substrate or workpiece
		Non-persistent contamination	Persistent contamination	
0	Minimising cleaning	Yes	Yes	Yes
0	Preparation prior to solvent or other types of cleaning	Yes		
0	Conventional solvent cleaning	Yes	Yes	
17.9.5	Cleaning with solvents with lower evaporation speed	Yes		
0	Cleaning with powerful solvents		Yes	
0	Cleaning with solvents with lower ozone forming potential (OFP)	Yes	Yes	Yes
17.9.6	Water-based cleaning	Yes	Yes	Yes
0	Cleaning by hand	Yes		Yes
17.9.7	Washing machines using solvents	Yes	Yes	
17.9.8	Cleaning with solvent recovery	Yes		
17.9.9	Cleaning with high pressure water spray		Yes	
17.9.10	Ultrasonic cleaning		Yes	Yes
17.9.11	Dry ice (CO <sub>2</sub> ) cleaning		Yes	Yes

### Cross-media effects

Changing from conventional techniques may result in more energy use, more waste water for treatment, or more waste being produced.

**Operational data**

See Description above, and the individual techniques described in Sections 0 to 17.9.9. Other techniques specifically used in certain industries are also discussed in the industry-specific sections.

**Technical considerations relevant to applicability**

See Description, above, and individual techniques in Sections 17.9.2 to 17.9.13 17.9.9 and techniques in Section ~~Error! Reference source not found.~~. Applicability of cleaning techniques in certain industries are also discussed in the industry-specific sections.

**Economics**

Site- and technique-specific.

**Driving force for implementation**

Workplace health and safety. Quality and customer demands.

**Example plants**

Cleaning is carried out in all installations.

**Reference literature**

[4, Intergraf and EGF, 1999, 104, Tempany, 2006]

**Minimising cleaning**

*Already covered elsewhere*

**Description:**

~~Techniques available for minimising cleaning agent or time for cleaning (ESVOC)  
Clean working practices and control of leaks and spills (STS-AT)~~

**Technical description:**

~~The following techniques all contribute to minimising cleaning:~~

- ~~• clean working practices~~
- ~~• controlling leaks and spillages (see Section 0)
  - ~~◦ regular inspection of working and storage areas~~
  - ~~◦ spillage plans to deal promptly with spillages of all sizes~~
  - ~~◦ prompt maintenance, such as stopping material leakages~~~~
- ~~• prevention of corrosion and soiling in storage and handling of materials such as metal workpieces (discussed in conjunction with water based treatments in the STM BREF).~~

**Environmental performance and operational information:**

~~Minimises cleaning materials used, especially solvents.~~

~~Operational data: No data submitted.~~

~~Cross-media effects: None.~~

**Technical considerations relevant to applicability:**

~~All installations.~~

~~Economics: Low cost.~~

~~Driving force for implementation: Health and safety: reducing unnecessary exposure to raw and cleaning materials, reducing risk of slips.~~

~~Example plants: Widely used.~~

**Reference literature:** [4, Intergraf and EGF, 1999] [27, VITO, 2003]

### 17.9.2 Prevention of paint deposition on areas and equipment by covers or foils

#### Description

Covering application areas and equipment (e.g. spray booth walls and robots) susceptible to overspray and drips, etc. with fabric covers or disposable foils where foils are not subject to tearing or wear

*TWG please provide more information*



Source: [Renault, Douai, FR 2017]

Figure 17.11: Robot applicator of sealant protected by fabric cover

### 17.9.3 Solids removal prior to full cleaning [~~Preparation prior to solvent or other types of cleaning~~]

#### Description

Minimising solvent-using cleaning by solids removal in a (dry) concentrated form, usually by hand, with or without the aid of small amounts of cleaning solvent.

#### Technical description

Removing as much of the coating material, paint or ink as possible from the equipment in its concentrated form reduces the amount of material to be removed using solvents and/or water. Raw material saving techniques may be used, such as described in Section 17.2.4.

Equipment parts are cleaned using solvents or water-based detergent systems. Physical rubbing, scrapping or scouring is applied by brushes, wipes ~~rags~~, abrasive pads, hand tools, etc. depending on the persistence of the contamination. The solvent is applied by rag or brush from a small supply (e.g. jug), tap or spray (fountain) or in open baths. Wipes ~~Rags~~ pre-impregnated with solvents can be used (e.g. see Sections 5.2.2.2, 6.4.3.4, and 17.2.2).

#### Achieved environmental benefits

Reduced solvent use in subsequent cleaning stages.

### **Environmental performance and operational information**

Reduces the use of solvents, cleaning materials and water that may require pretreatment prior to discharge. Can save raw materials.

Solvent emissions can be controlled by the following:

- Limiting the amount of solvent (e.g. by measuring and restricting the amount to be used in a jug, using pre-impregnated wipes, etc.).
- Using volatile solvents by hand, and allowing the spent solvent to overflow immediately into a closed container. No open surface of liquid solvent should be exposed in the workstation close to the object to be cleaned. This also reduces occupational exposure. Equipment is available that consists of a closed drum containing solvents that can be pumped when required through a tap or sprayed onto the object to be cleaned in a partially enclosed work area above the drum. The surplus solvent runs back (through coarse filters) into the drum. The solvent is pumped from the surface of the solvent, leaving contamination to settle out. The solvent may be recycled when it can no longer be used.
- Using low-toxicity solvents ~~that have a high flashpoint, a high boiling point, or a low photochemical/ozone-forming potential~~ (see Section 17.6.2).

### **Cross-media effects**

Consumption of solvents, emissions of VOCs and solvent/paint waste.

### **Technical considerations relevant to applicability**

Some hand cleaning is almost inevitable in all sectors, although workplace health and safety often limits its use.

May increase downtime. May increase staff contact with hazardous materials.

Workplace health and safety may limit the application of this technique.

### **Economics**

Low cost, but may increase downtime.

### **Driving force for implementation**

~~No data submitted.~~ Low cost. Where automated methods cannot be applied, do not clean sufficiently or may damage the parts to be cleaned.

### **Example plants**

Widely used.

### **Reference literature**

[4, Intergraf and EGF, 1999] [13, DFIU and IFARE, 2002] [27, VITO, 2003] [180, COM, 2017]

## **17.9.4 Manual cleaning with pre-impregnated wipes**

### **Description**

Wipes pre-impregnated with cleaning agents may be used for manual cleaning. Cleaning agents may be solvent-based, low-volatility solvents or solvent-free.

### **Technical description**

As the wipes are pre-impregnated, this limits the amount and type of solvents used. Wipes may be disposable or recycled for cleaning and reuse.

### **Achieved environmental benefits**



Minimised and controlled solvent usage, reducing solvent emissions.

## **Environmental performance and operational information**

### **Cross-media effects**

#### **Technical considerations relevant to applicability**

Health and safety in the workplace.

#### **Economics**

Low cost.

### **Driving force for implementation**

#### **Example plants**

Used in the aircraft industry.

#### **Reference literature**

No information provided

## **Collection of solvents (from cleaning) and recovery of solvents**

*Collection of cleaning agents and solvent recovery by distillation. See 17.12.2.1.*

## **Conventional Solvent cleaning**

*Combined in Sections 17.9.3 and 17.9.5 covering the inevitable manual cleaning*

### **Description**

Oil, grease and dirt are removed from metal or plastic substrates with solvents. This is usually by immersion in a vat of solvent or the solvent vapour above a heated liquid. Room temperature cleaning can be carried out manually.

### **Technical description**

Cleaning using solvents can be carried out at room temperature or with heating. The vats may be open or closed (more usually closed for health and safety reasons), and may be used with ultrasonic systems. Manually cleaning can be carried out with a rag, a brush, a spray or 'fountain' with low toxicity solvents, in open baths or in closed systems

Cleaning using hot solvents uses closed or semi-closed vessels (e.g. see Section 17.9.6). The flammability risk has to be adequately controlled by working well below the flashpoint or under inert atmospheres.

### **Achieved environmental benefits**

None reported.

### **Environmental performance and operational information**

Often uses highly volatile and/or halogenated VOCs. Cleaning processes with organic solvents account for about 20 % of total VOC emissions from paint shops. 80 % of solvent emissions from cleaning processes can be reduced by using closed systems for the cleaning of guns and applicators.

Solvent emissions or their impact can be reduced by substituting different solvents, e.g. those with higher flashpoints, more power cleaning action or lower photochemical/ozone forming potential (see Section 17.9.6).

In some cases, solvents can be replaced by water based cleaning agents (see Section 17.9.6).

### **Cross-media effects**

Consumption of solvents, emission of VOCs and solvent/paint waste.

### **Technical considerations relevant to applicability**

~~Widely used where compatible with materials. Solvent based cleaning processes are necessary for the delivery and application equipment in each paint shop. These processes are not applied in the coating of wood and furniture as they are not necessary and remove oils from the wood~~

### **Economics**

~~The vat based systems cost EUR 150–3000.~~

### **Driving force for implementation**

~~Quality; compatibility with coatings in use; customer demands.~~

### **Example plants**

~~Widely used.~~

### **Reference literature**

~~[13, DFIU and IFARE, 2002] [38, TWG, 2004].~~

## **17.9.5 Low-volatility cleaning agents**

[78, TWG, 2005]

*TWG please update with fresh information*

### **Description**

Application of low-volatility solvents as cleaning agents, usually with more powerful cleaning action, reducing or eliminating evaporation.

### **Technical description**

As the coating is usually most readily soluble or resuspended in the original solvents, occasional use of traditional low flashpoint cleaning agents will be necessary to assist in difficult cleaning tasks. A small amount of these (e.g. some 5 % of the total) will have to be kept in stock.

The evaporation speed of solvents determines the amount of solvent that will evaporate during the cleaning activity and the later storage of the contaminated wipes (a standard test is used: DIN 53170). Low volatility cleaning agents may be classified as: flashpoint of  $> 40$  °C; flashpoint of  $> 55$  °C; flashpoint of  $> 100$  °C (high boiling, HBS); vegetable cleaning agents (VCAs); powerful non-volatile solvents

The evaporation speed of traditional solvents is significantly higher than the evaporation speed of solvents with a flashpoint of  $> 40$  °C. Consequently, the evaporation during cleaning can be reduced by using medium flashpoint solvents. These solvents may be useful as an intermediate step when switching from volatile cleaning agents to less volatile cleaning agents.

The evaporation speed of traditional solvents can be some 100 times higher than the evaporation speed of solvents with a flashpoint of  $> 55$  °C. Consequently, the evaporation during cleaning can be reduced dramatically by using high flashpoint solvents.

Cleaning agents which have a flashpoint of  $> 100$  °C are also called high-boiling solvents (HBS). They show even less evaporation (nearly zero) than solvents with a flashpoint of  $> 55$  °C. Vegetable cleaning agents (VCAs) are included in the group of cleaning agents with a flashpoint  $> 100$  °C (see Section 17.9.5). The first generation of VCAs were simply refined vegetable oils, which were found to be rather thick and difficult to handle. The present generation of VCAs are mono-esters of different fatty acids with differing degrees of saturation

(iodine numbers) and fatty acid content (acid numbers). Automatic cleaning systems especially constructed to be used with VCAs are available.

Powerful solvents such as *n*-methyl-2-pyrrolidone (boiling point 202 °C, flashpoint 95 °C) and ethanolamine (boiling point 170 °C, flashpoint 85 °C, vapour pressure 0.2 mm Hg) can be used where a powerful solvent action is required, usually in cleaning. They can replace halogenated solvents.

The evaporation speed of traditional solvents, e.g. in printing, toluene and ethyl acetate, is higher than the evaporation speed of solvents with medium and high flashpoints. Consequently, the evaporation during cleaning can be reduced by using the latter. Data on the evaporation speed can be obtained from the supplier, if not provided to the user of the solvent. If this information is not available, the flashpoint of a solvent is a good indication of its evaporation speed, and all lower flashpoints should be indicated on the packaging of the solvent.

See Section 17.9. The evaporation speed of solvents determines the amount of solvent that will evaporate during the cleaning activity and the later storage of the contaminated wipes (a standard test is used: DIN 53170). The evaporation speed of traditional solvents, e.g. in printing, toluene and ethyl acetate, is higher than the evaporation speed of solvents with medium and high flashpoints. Consequently, the evaporation during cleaning can be reduced by using the latter. Data on the evaporation speed can be obtained from the supplier, if not provided to the user of the solvent. If this information is not available, the flashpoint of a solvent is a good indication of its evaporation speed, and all lower flashpoints should be indicated on the packaging of the solvent.

Using medium and high flashpoint cleaning agents also has some health and safety advantages, because the exposure of personnel to the evaporated solvents will be reduced. However, as very low OELs sometimes occur, e.g. 1 or 2 ppm versus 150 ppm for ethyl acetate, these advantages occur when the alternative cleaning agent meets the following criteria:

- there is not a substantially lower occupational exposure limit
- the change in solvent does not lead to heating being required
- the solvent is not dried by forced evaporation with HP air.

As the coating is usually most readily soluble or resuspended in the original solvents, occasional use of traditional low flashpoint cleaning agents will be necessary to assist in difficult cleaning tasks. A small amount of these (e.g. some 5 % of the total) will have to be kept in stock. For example, HBS or other low volatility solvents are not applicable to all printing plants. Inks that are based on volatile solvents, when dry, dissolve easily in the same solvent which they originally contained. Using solvents other than the original solvent is generally counterproductive. One of the reasons is that it is not possible to use existing machinery for in-house distillation and reuse when changing to HBS. In-house filtering systems are under development for HBS. Other examples of the occasions where volatile cleaning agents will need to be used are the following (see Section 17.9):

- cleaning dampening rollers
- maintenance
- cleaning UV curing inks
- difficult colour changes.

Where alternative solvents with lower volatility/higher flashpoint are used for cleaning floors, these solvents do not (by definition) evaporate rapidly, and therefore leave the floor slippery. It is therefore necessary to dry the floors, sometimes with small quantities of volatile solvents. [97, TWG, 2006]

### **Achieved environmental benefits**

Reduced emissions to air during use and storage of used solvents and cleaning materials and reduced hazardous waste generation. The risk of soil contamination from solvent-enriched air is also reduced.

As less solvent evaporates, solvent stays in contact with soiling and solvent consumption decreases.

Reduction of VOC emissions to air depends on the situation at the start: changing from solvents with a flashpoint of < 21 °C achieves a reduction of about 90 %; changing from solvents with a flashpoint of 21–55 °C can result in a reduction of about 50 %.

These VCAs are made from a renewable source and will, therefore, not increase the emissions of greenhouse gases.

### **Environmental performance and operational information**

Higher flashpoint solvents may not be as effective and efficient in cleaning as traditional solvents and the cleaning will require more time, but with experience, the results tend to become acceptable.

It is not possible to use existing equipment for in house distillation and reuse when changing to HBS. In-house filtering systems are under development for HBS.

It is important to consider the health and safety and environmental impacts of low volatility agents (see Section 17.6.1). For instance, very low OELs sometimes occur, e.g. 1 ppm or 2 ppm versus 150 ppm for ethyl acetate. Some VCAs are reported to possibly contain up to 15 % solvents or toxic ingredients (although these have not been defined further). Obviously, such VCAs may not add any environmental value or health and safety protection. The use of VCAs discussed in this section is based on VCAs that are free of solvents and toxic ingredients.

When used at room temperature, powerful low volatility solvents have no emissions and limited health and safety equipment is needed. However, when used at a higher temperature to improve their effectiveness, these advantages disappear

Advantages occur when the alternative cleaning agent meets the following criteria:

- there is not a substantially lower occupational exposure limit or other toxicological impacts;
- the change in solvent does not lead to heating being required;
- the solvent is not dried by forced evaporation with HP air.

N-methyl-2-pyrrolidone (a powerful, non-volatile solvent) has now been classified as CMR.

Cleaning with HBS requires an after-cleaning that is carried out with water. The water consumption and effluent discharge will also increase, because HBS is normally diluted with water. Water HBS mixtures can be treated by applying a filtration after which the HBS can be reused and the water residue can normally be discharged into the sewerage system.

Other examples of the occasions where volatile cleaning agents will need to be used are the following (see Section 17.9 ):

- cleaning dampening rollers;
- maintenance;
- cleaning UV curing inks;
- difficult colour changes.

Where alternative solvents with lower volatility/higher flashpoint are used for cleaning floors, these solvents do not (by definition) evaporate rapidly, and therefore leave the floor slippery. It is therefore necessary to dry the floors, sometimes with small quantities of volatile solvents. [97, TWG, 2006]

### **Cross-media effects**

In printing, paper losses may increase, as after intermediate cleaning it takes longer for the cleaning agents to disappear which might result in the breaking of the web.

The less solvent that evaporates, more maybe left as waste to be treated or disposed of. Cleaning with HBS and VCAs requires an after-cleaning that is carried out with water, increasing water consumption and effluent discharge.

### **Technical considerations relevant to applicability**

Not used in all industries.

These solvents are applied in manual and automatic cleaning. They are commonly applied in heatset where mixtures of VCAs and high flashpoints (55–100 °C) are often used in order to attain the right drying speed.

In the printing industry, where automatic cleaning systems are used in offset printing plants, it should be ~~understood~~ confirmed that there are no manufacturers' objections against the use of VCAs. Some automatic systems may be damaged by the use of these products. Automatic systems from before 1996 might especially require some adaptations in the dosing and spraying systems. Sometimes seals have to be replaced.

~~In heatset offset~~, Applying HBS requires a different working method compared to conventional solvents. The results of applying HBS are therefore variable, however, often the results are favourable. This is mostly the case where presses are cleaned by hand.

Applying VCAs requires a different working method compared to conventional solvents, therefore, the results are variable; however, often the results are favourable. This is mostly the case where presses are cleaned by hand. However, training and the gaining of experience helps.

VCAs. Applicable in sheetfed offset plants. In coldset and heatset web offset processes, it is used only for the final cleaning of the press. This is because during printing, the rinse-water can easily break the paper web. A survey carried out in Denmark showed that about 65 % of the sheetfed offset printers use VCAs regularly, only using volatile solvents when it is necessary to remove dried ink. The consumption of VCAs at those plants accounts for about 2 % of all the solvents used. Other reports, e.g. from the Netherlands, show that these cleaning agents are not applicable in heatset and not always in sheetfed. It is also reported that in heatset the difference in emissions between HBS and VCAs does not justify the extra costs and time lost.

In flexible packaging, high-flashpoint solvents are commonly used in small quantities to remove very persistent contaminations. For daily cleaning of cleaning machines, however, these high-flashpoint cleaning agents are not commonly used, although some experiments are being carried out which have not been successful yet:

- ~~applicable to heatset offset printing plants;~~
- ~~HBS can be applied in manual and automatic cleaning.~~

The uses of VCAs should be limited to those whose toxicology and other cross-media effects are known.

### **Economics**

Generally, this technique is self-funding, however, the following conditions have to be taken into account (for example in the printing industries):

- except for automatic cleaning in old plants where the retrofitting costs may be high;
- modern automatic cleaning units, if they still use high volatility solvents, only use a few ml per cleaning cycle;
- even a small loss in production time per cleaning cycle makes this technique very expensive if expressed as EUR/kg not emitted.

In printing, as cleaning may require more time and as press time is very expensive, the use of lower volatility solvents rapidly becomes prohibitively expensive if indeed press time is lost. For example, loss in production time due to slower evaporation of the solvent can easily run up costs of over EUR 1 000 per hour in heatset printing.

VCA: Often VCAs are four times more expensive than conventional cleaning agents. However, the volume of VCAs needed to clean a constant blanket surface is 1/2 of the volume of conventional cleaning agents. Generally, this technique is self-funding, however, the following conditions have to be taken into account:

Powerful non-volatiles: More expensive than traditional solvents.

### Example plants

Widely used, but not applicable in all situations.

### Reference literature

[4, Intergraf and EGF, 1999] [14, Aminal, et al., 2002] [38, TWG, 2004] [54, BMLFUW Austria, 2003] [12, Netherland, 1996] [116, ESIG, 2005] [18, UBA Germany, 2003] [8, Nordic Council of Ministers, 1998] [78, TWG, 2005] [11, IMPEL, 2000] [128, TW [97, TWG, 2006]

### ~~Cleaning with solvents with lower evaporation speed~~

*Combined with Section 17.9.5*

### ~~Cleaning with powerful solvents~~

*Combined with Section 17.9.5*

### ~~Cleaning with solvents with lower ozone-forming potential~~

*Combined with Section 17.9.5*

## 17.9.6 Water-based cleaning

*This technique is described fully in the STM BREF*

### Description

Cleaning systems using water-based detergents or water-miscible solvents such as alcohols or glycols.

### Technical description

Water-based cleaning can be used on a continuous basis in vats using water-based cleaning or degreasing techniques based on detergent systems. It is also used to clean substrates or workpieces for subsequent water-based treatment techniques, e.g. see Section 17.7.1. Water-based systems can also be used to clean components and sub-assemblies on a batch basis manually or in washing machines for cleaning process lines, equipment and infrastructure, see also Section 17.9.9.

There are a range of chemical systems used, based on combining detergents with alkalis and others substances, depending on the substrates and the materials to be removed. These, and their associated maintenance options, are discussed in the STM BREF.

In paint shops with water-based paints, alcohol or glycol/deionised water mixtures (butyl glycol/water) are used instead of pure organic solvents. It is used for the primer and base coat process.

In some cases, rinsing media based on tensides (< 1% organic solvents) can be used for cleaning processes.

#### **Achieved environmental benefits**

Reduced solvent consumption and fugitive VOC emissions.

#### **Environmental performance and operational information**

No information provided.

#### **Cross-media effects**

While the solvent content can be significantly reduced, it should be noted that water-based cleaners may contain up to 15 % solvent.

#### **Technical considerations relevant to applicability**

Depending on kind & degree of contamination (i.e. 2K or UV cured difficult)

Water-based cleaning agents are used in the automotive industry where water-based paints are used.

Used also in flexography and non-publication gravure industry

#### **Economics**

More expensive than conventional solvent.

#### **Driving force for implementation**

No information provided.

#### **Example plants**

In all VW plants water-based cleaning agents are used for primer and base coat.

Examples for rinsing medias based on tensides: VW Wolfsburg, Hannover, Emden, Wrzesnia

For the flexography sector: #014

#### **Reference literature**

[1, INTERGRAF and EGF, 1999] [38, TWG, 2004] [78, TWG, 2005][183, ACEA, 2017] [197, FPE, 2017]

#### **Cleaning by hand**

*Combined with 17.9.3*

### **17.9.7 Enclosed washing machines using solvents**

#### **Description**

Automatic batch solvent-based cleaning/degreasing in encapsulated washing machines with integrated solvent recovery or extraction to treatment.

#### **Technical description**

An enclosed machine which is loaded with components on a batch basis. The components can be either workpieces to be coated or process machine parts to be cleaned during maintenance or

between orders. The machine contains solvents which are used to clean the parts by (i) immersion (ii) spray or (iii) a vapour phase of low boiling solvent which condenses on the components, therefore always depositing clean solvent on the components to be cleaned. The solvents are contained, and collected for reuse. The solvent is usually heated.

### **Achieved environmental benefits**

Solvent emissions are reduced significantly compared with uncontained cleaning.



Source: [Amcor Flexibles Europe and Americas, HP Laminates, Ghent, BE]

Figure 17.12: Enclosed automatic washing machines

### **Environmental performance and operational information**

The emission of solvent vapours from venting can be reduced considerably by venting to a waste gas treatment system in the installation or to absorption in dedicated cylinders containing activated carbon.

~~Some cases of difficult deposits or persistent contamination require removal with halogenated solvents. These solvents can be used in fully enclosed systems with treatment of the vented solvents.~~ Note that Article 57, IED requires substitution as soon as possible and ELVs apply (Annex VII). *TWG please update on use*

### **Cross-media effects**

The vessel of the machine holding the parts requires venting of the solvent vapours before the contents can be removed. These vented vapours are sometimes released to air.

Energy is used in pumping solvent.

Activated carbon is used if absorption cylinders are used, and the carbon needs regenerating or discarding as waste.

### **Technical considerations relevant to applicability**

#### **Economics**

No data submitted.

#### **Driving force for implementation**



Workplace health and safety. Note that the IED sets specific ELVs for some halogenated solvents.

**Example plants**

Widely used in many industries.

**Reference literature**

[108, ESVCCG, 2006]

**17.9.8 Purging with solvent recovery****Cleaning with solvent recovery****Description**

Solvent is used to purge the guns/applicators and lines between colour changes to prevent cross contamination. The purge and cleaning solvent can be collected, stored and reused.

**Technical description**

~~Solvent is used to purge the guns/applicators and lines between colour changes to prevent cross contamination. The purge and cleaning solvent can be collected, stored and reused~~

Purging with solvent is used to clean the guns/applicators and lines between colour changes to prevent cross contamination. Cleaning solvent is used to clean the equipment and booths. The purge and cleaning solvent can be collected, stored and reused as a solvent feedstock or destroyed. Some modern paint shops plants are equipped with a recovery installation for the used cleaning agents.

Modern paint supply equipment including recovery of the purge solvents is commonly applied. Recovery is by piping the cleaning agents from the application equipment to storage tanks

**Achieved environmental benefits**

Typically ~~80-90%~~ Most of cleaning and purge solvent can be recovered for reuse.

**Cross-media effects**

No data submitted.

**Operational data**

Problems are reported with two-component clear-coat materials, which frequently lead to clogging of the recovery tank piping.

**Applicability**

Widely used for solvent based cleaning process.

~~This system can be applied to solvent based paint application processes and any operation where solvents are used to clean booths. Collected solvent can be treated for reuse within the process or alternatively be dispatched from the site and processed for reuse by the original operator or a third party.~~

**Economics**

In the automotive industry, a typical solvent recovery system costs EUR 0.4 million per spray booth to install in 2004. *TWG please update the information*

A saving will be achieved because of a reduced consumption of solvents and reduced amounts of hazardous waste. In large plants, the savings will approximately outweigh the investment.

**Driving force for implementation**

Solvent recycling and VOC emission reduction.

### **Example plants**

Ford, Europe. Standard practice in the automotive industry. Widely used in other sectors.

### **Reference literature**

[1, INTERGRAF and EGF, 1999] [5, DFIU and IFARE, 2002] [26, CITEPA, 2003] [68, ACEA, 2004, 38, TWG, 2004]

## **17.9.9 Cleaning with high-pressure water spray**

*TWG please update the information*

### **Description**

Automatic batch cleaning of components using water-based cleaning systems. High-pressure water spray and sodium bicarbonate systems or similar may also be used for cleaning of machine parts. ~~and doctor blades (in printing) is carried out with high pressure water spray and sodium bicarbonate or similar cleaning systems using~~

### **Achieved environmental benefits**

Reduction of solvent emissions.

### **Cross-media effects**

Increased consumption of water and more waste water will arise.

### **Operational data**

Commonly applied.

### **Applicability**

This technique is used for in-depth cleaning of doctor blades, cylinders and anilox rollers used in flexible packaging. Sodium carbonate is added to the high pressure water.

### **Economics**

No data submitted.

### **Driving force for implementation**

Workplace health and safety.

### **Example plants**

No data submitted.

### **Reference literature**

[4, Intergraf and EGF, 1999, 38, TWG, 2004]

## **17.9.10 Ultrasonic cleaning**

### **Description**

Cleaning in a liquid using high-frequency vibrations to loosen the adhered contamination.

### **Technical description**

An ultrasonic cleaner generates high frequency vibrations through a liquid (usually water-based detergents), i.e. ranging from about 20 000 to 100 000 cycles per second. The vibrations create microscopic bubbles in the liquid that then collapse on items that are immersed in the liquid, creating a cleaning action.

### **Achieved environmental benefits**

No solvent-based cleaning agents are used and VOC emissions are eliminated.

**Cross-media effects**

Noise levels might increase.

**Operational data**

No data submitted.

**Applicability**

Applied in flexible packaging printing for in-depth cleaning of cylinders and anilox rollers.

**Economics**

No data submitted.

**Driving force for implementation**

Workplace health and safety.

**Example plants**

No data submitted.

**Reference literature**

[8, Nordic Council of Ministers, 1998] [38, TWG, 2004] [59, EIPPCB, 2005]

**17.9.11 Dry ice (CO<sub>2</sub>) cleaning****Description**

Cleaning of metallic or plastic surfaces by blasting with CO<sub>2</sub> chips or snow.

~~Dried paint or ink can be removed by blasting with dry ice pellets.~~

**Achieved environmental benefits**

Solvent emissions are completely avoided.

**Cross-media effects**

Blasting requires energy and creates noise (in-house) and dust from removed paint or ink.

**Environmental performance and operational information**

The preparation takes a lot of time as the parts of the machine to be cleaned must be totally isolated to prevent damage to other parts.

**Applicability**

Widely applicable for maintenance cleaning rather than daily cleaning processes as disassembly of machine parts is usually involved.

In printing, the technique is used to get rid of very persistent contamination on parts of the presses. It is applied every few months for a periodic intensive cleaning in publication gravure and heatset plants, where normally toluene or special mixtures of solvents are used as a cleaning solvent.

**Economics**

Costs are comparable to conventional cleaning techniques.

**Driving force for implementation**

Workplace health and safety

**Example plants**

Used in flexography, packaging, publication gravure and heatset plants Europe-wide.

**Reference literature**

### 17.9.12 CO<sub>2</sub> snow cleaning

[190, ESVOC, 2017]

#### Description

Surface cleaning by use of accelerated CO<sub>2</sub> snow with an applicator (nozzle array) installed on a robot.

#### Technical description

Liquid CO<sub>2</sub> is passing the nozzle with pressure and cooling down due to the expansion behind the nozzle. The CO<sub>2</sub> ice crystals are accelerated by air (see example below).

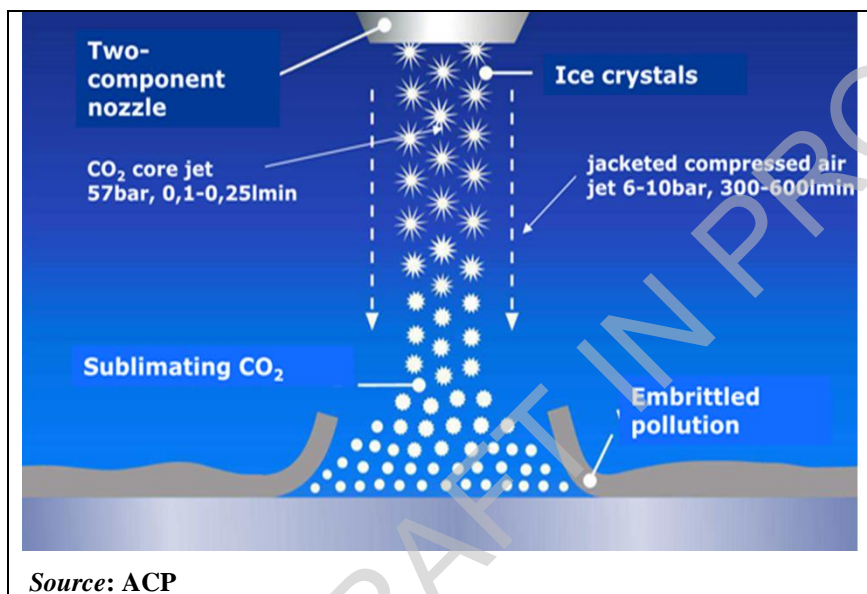


Figure 17.13: Liquid CO<sub>2</sub> discharge

The energy which is released when the ice crystals collide with the surface to be cleaned removes dust and other dirt.

The CO<sub>2</sub> snow cleaning installation consists of the following components:

- robot with six or seven axis equipped with application equipment;
- process valves installed on the robot housing between Arm1 and Arm 2;
- applicator (nozzle arrays) installed on the robot hand axis;
- application cabinet outside the robot zone:
  - CO<sub>2</sub> cooler;
  - air filter device;
  - robot controller cabinet;
- CO<sub>2</sub> supply system consisting of CO<sub>2</sub> tank, compressor and cooling system.



Figure 17.14:(a) Applicator robot (b) High pressure CO<sub>2</sub> tank (c) Low pressure CO<sub>2</sub> tank (Dürr)

#### Achieved environmental benefits

- Lower energy use.
- No dryer needed, reduced energy consumption.
- No use of water/chemicals.

#### Environmental performance and operational information

Replacement of Power Wash pretreatment and water dryer oven.

Lower maintenance:

- no dosing of chemicals needed;
- flexible system with good reachability by use of the robot;
- same operation like application robots;
- same spares like for the application robots.

Process advantages

- no use of water/chemicals;
- only a few process parameters to be adjusted;
- elimination of surface errors caused by water.

Operation environment needed:

- soundproofed booth design (noise level outside the booth;
- < 75 dBA, noise level on the nozzles approximately 105–110 dBA);
- air return plenum under the conveyor;
- no non-ventilated areas in the booth;
- safety protected booth doors and booth entrance;
- operation of the booth must be in underpressure;
- fresh air blade in the entrance and exit of the booth in order to keep CO<sub>2</sub> concentration inside of the booth;
- the MAK values must be controlled inside and outside the booth with CO<sub>2</sub> sensors, category 3, redundant:
  - air downdraft velocity 0.4–0.5 m/s;
  - fresh air portion approximately 20–25 %;
  - temperature > 20 °C;
  - relative humidity max. 55 %;
  - ionisation portals after the cleaning zone.

#### Cross-media effects

No information provided.

#### Technical considerations relevant to applicability

Applied in the following sectors:

- plastic parts cleaning; and
- general industrial components.

Some residues cannot be removed by snow cleaning, therefore the following preconditions have to be met:

- no outside storage of parts in open air;
- no finger prints, grease, oil, mould release agents and other strong adhesive dirt / residues at the part;
- small time frame between moulding process and painting;
- clean room principle for the whole paint line necessary.

### **Economics**

- Invest cost for retrofitting.
- Cost reduction due to material and energy savings.
- Higher first run (no surface errors caused by water).

### **Driving force for implementation**

- Higher quality, no water spots on the bumper surface. Elimination of surface errors caused by water.
- Reduction of cost per unit.
- No blowing zone necessary.
- Reduction of footprint. Only one booth for the cleaning robot. No cooling zone necessary.

### **Example plants**

(Source Dürr):

Rehau Viechtach, Germany, 2008.

Rehau Port Elizabeth, South Africa, 2009.

Plastic Omnium, Gliwice, Poland, 2012.

Rehau Győr, Hungary, 2013.

Rehau Port Elizabeth, South Africa, 2013.

Volkswagen Wolfsburg, Germany, 2013.

(Source Eisenmann):

Plastic omnium Mexico.

Plastic omnium Chattanooga.

Daimler.

### **Reference literature**

No reference literature provided.

## **17.9.13 Plastic shot blast cleaning**

### **Description**

Plastic shot blasting of panel jigs and body carriers to remove excess paint build-up.

### **Technical description**

Customised shot blasting cabinets are used for jigs, with specified range of blast pressure and nozzle size to achieve optimum clean, depending on size and contamination level of jigs.

Customised compartment required for larger equipment such as paint dollies and scrap painted bumper parts.

Successful trials carried out

**Achieved environmental benefits**

Elimination of use of hazardous cleaning chemicals previously used.

**Environmental performance and operational information**

- Cleaning method does not use harmful chemicals.
- Extends life of production equipment and tools.
- Potential to minimise scrap plastic painted parts by allowing removal of paint and re-spray.
- To be trialled on scrap plastic bumpers to allow re-painting.

**Cross-media effects**

No information provided.

**Technical considerations relevant to applicability**

Several other materials were considered for shot blasting. These included metal, sand and glass. All were too abrasive and caused damage to the jigs after several cleans.

Other cleaning technologies considered:

- Aqueous energy ultrasonic tank considered was unable to breakdown 2K clear coat.
- Insulated reactor containing sand heated to 450 °C caused damage due to abrasive nature of the process.

**Economics**

- Reduced cleaning cost by 50 %.
- Requires initial cost investment to buy shot blasting equipment and the custom building of chamber for cleaning larger body carriers.

**Driving force for implementation**

- Cleaning cost reduction.
- Reduced contamination of jigs and transfer to painted bodies.
- Improved quality and less re-work.

**Example plants**

Honda of the UK Manufacturing Ltd. (HUM), Swindon, UK.

**Reference literature**

[ACEA\_HUM1]

**Replacement of cleaning agents (substitution)**

*Merged and replaced by Section 17.9.5*

**Cleaning agents with a flashpoint of > 40 °C**

*Combined in Section 17.9.5*

**Cleaning agents with a flashpoint of > 55 °C**

*Combined in Section 17.9.5*

**Cleaning agents with a flashpoint of >100 °C**

*Combined in Section 17.9.5*

**Vegetable cleaning agents (VCAs)**

*Combined in Section 17.9.5*

**Powerful non-volatile solvents**

*Combined in Section 17.9.5*

**Water-based cleaning**

See Section 17.9.6.

**Substitution: using less harmful substances – general principles**

Merged with Section 17.6.1, Systematic evaluation to reduce environmental impact

**Using solvents with lower ozone-forming potential (OFP)**

Moved to Section 17.6

**Replacement of halogenated solvents**

Moved to Section 17.6

**Replacement of solvents and other materials with CMR properties (substitution)**

Moved to Section 17.6

**Water-based cleaning agents**

Merged with Section 17.9.6 Water-based cleaning

WORKING DRAFT IN PROGRESS



## 17.10 Waste gas treatment

This section discusses applied treatment systems for waste gases containing solvent. It not only discusses the different types of treatments that are available, but also the design and layout. The section also covers techniques to optimise or minimise the airflow that has to be treated and techniques to recover the abated solvents, such as distillation.

### 17.10.1 Design, optimisation and management of extraction and abatement techniques

#### 17.10.1.1 Selection, design and optimisation of the waste gas extraction and abatement system

##### Description

The correct system selection, design and optimisation of the waste gas extraction system and of the abatement system has a large impact on energy consumption and VOC emissions.

##### Technical description

Air extraction systems containing solvents are usually primarily designed to keep atmospheres within working areas and equipment well below the LEL and the solvent concentrations lower than the OEL. The extraction of key point sources of solvents are led to waste gas treatment systems.

In some cases, (such as drying ovens, washing machines using solvents), the air is exhausted to treatment with the primary aim of reducing solvent emissions. Also, in many cases, the original purpose of treating the waste gas was to reduce odour.

The dimensioning of the extraction system and the selection of the abatement technique take into account:

- the emissions pattern (continuous/discontinuous);
- the energy content of off-gases and the effect of energy consumption below autothermal conditions;
- the costs and benefits of treating emissions with low VOC concentrations, in terms of energy consumption.

The design of the extraction systems should take into account:

- the amount of air to be extracted;
- the type and the likely level of solvents;
- the type of treatment and its cost-benefit and cross-media effects (e.g. material, energy consumption);
- the number of hours per year in operation;
- using decentralised/dedicated treatment systems so breakdown/repair only affects the systems in question (see Section 17.10.1.1.1).

Extraction of a large volume of air in proportion to solvent increases the size of the abatement system and may increase the amount of energy required as support fuel for combustion.

Fugitive emissions that are not caught by extraction systems and waste gas treatment may often form the major part of the solvent emissions (for example, see Section 11.3). This must be considered when designing an extraction and abatement system.

An example of considering the cross-media effects between flexographic printing with water-based and solvent-based inks is given in the ECM REF [50, COM, 2005].

Annex 21.9 provides a summary of waste gas treatment techniques (oxidation, adsorption, condensation and biological treatment) and their applicability. A comparison of the removal efficiencies of the most widely used techniques is given for different types of solvents at different inlet concentrations. [97, TWG, 2006]

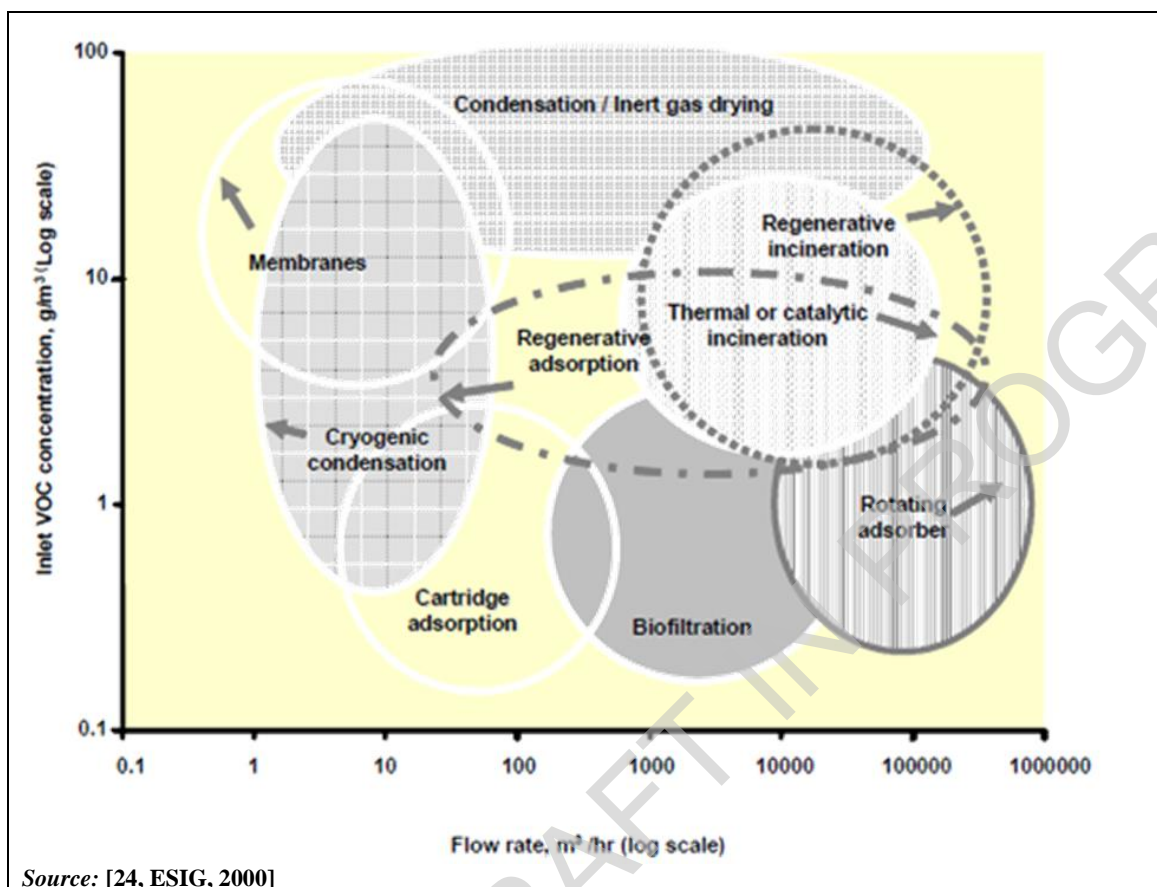


Figure 17.14: Overview of application ranges of the available VOC abatement technologies

Figure 17.14 gives an overview of application ranges of the available VOC abatement technologies up to 2 000. Industry comments that wet scrubbing is only used for particulate removal, condensation needs to be combined with inert gas drying and is used for much higher concentrations and regenerative incineration (oxidation) is applied much more widely today (< 5000 → 100 000 m<sup>3</sup>/h) [38, TWG, 2004].

The following considerations can assist in the system selection, design and optimisation, although expert guidance may be sought:

- **Discontinuous emissions:** for discontinuous processes, variable and small loads techniques such as simple thermal oxidation (incineration) or adsorption (e.g. on cartridges) are most cost-effective.
- **Selection of thermal treatment for continuous operation** [62, Verspoor and manufacturer], 2005]: where the emissions are continuous, and multiple bed oxidisers are considered. Energy demands for air extraction and for support fuel are higher. Table 17.6 shows treatment required to achieve different emission levels.

See also Section 17.10.3: Maintaining VOC concentration prior to treatment.

Table 17.6: Influence of the emission value on choice of two- or three-bed oxidiser

VOC concentration in waste gas after treatment (mg C/Nm <sup>3</sup> )	Treatment required
20 mg C as 24 h average	3-bed oxidiser
50 mg C as 24 h average	2- or 3-bed oxidiser (depending on maximum inlet VOCs)
100 mg C as 24 h average	2-bed oxidiser
20 mg C at all times	3-bed oxidiser
50 mg C at all times	3-bed oxidiser
100 mg C at all times	3-bed oxidiser
<i>Source: [62, Verspoor and manufacturer], 2005]</i>	

The investment costs of two-bed oxidisers are 10–15 % lower than for three-bed oxidisers. In combustion plants with regenerative preheating (regenerative thermal oxidation, RTO plants), by far the greatest share of process energy is recovered by integrated heat exchangers (>95 %). Therefore, the energy requirement in the waste gas treatment for achieving 20 mg/m<sup>3</sup> of treated gas is not significantly higher than the energy needed for achieving only 50 mg/m<sup>3</sup> or 100 mg/m<sup>3</sup>. However, there is higher energy consumption for the main fan of the extraction system, and higher maintenance costs. If process temperatures are lowered because higher VOC concentrations in treated gas are permitted, CO emissions may rise considerably

- **Effect of energy consumption below autothermal conditions:** for the effect on the running cost of the incinerator when the average solvent content structurally reduces over time, due to (for instance) a decrease in solvent content of the coating materials in use, see
- Figure 17.15. This shows data for an incinerator on a flex pack plant. The amount of gas used after the autothermal point increases exponentially for medium and low flows.

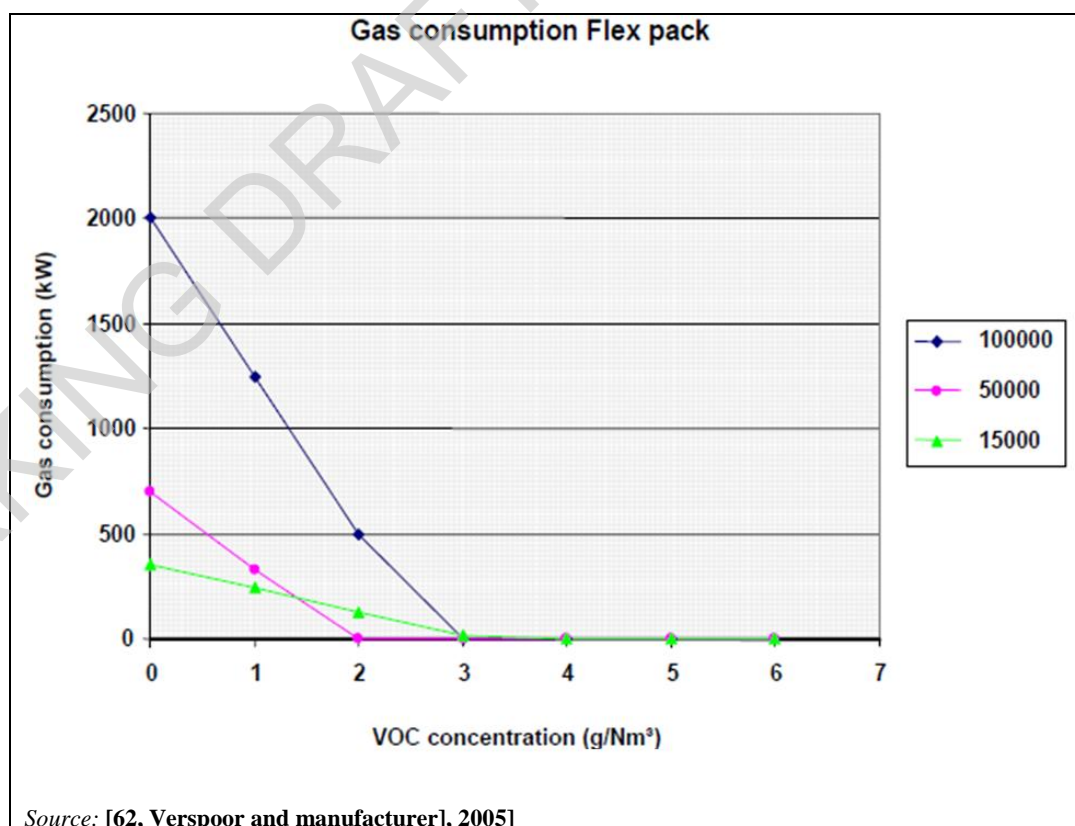


Figure 17.15: Example of gas consumption below autothermal point for flex pack

- **Cost-benefit of energy consumption to control low solvent emissions:** the ECM REF describes ways of calculating and interpreting cross-media effects for alternative process options by collating emissions into seven environmental effects (themes). These effects can be compared using scales of relative effect for the individual substances released or their toxicities (see also Section 17.6.1). However, it is difficult to compare one effect against another, such as photochemical ozone formation against global warming potential, and further cross-media evaluation is required.

An alternative method to compare these different effects is to compare the costs of the negative externalities (damages or negative marginal social costs), in this case the damage to the environment including human health. There may be fewer data available for this, but data are available for emissions to air (see below, in this section). This technique may be used to compare the effectiveness of different courses of action. For example, burning a support fuel to achieve lower VOC emissions in waste gas can be compared with further measures to reduce fugitive emissions. The tonnes of CO<sub>2</sub> released a year can be calculated for burning additional fuel to destroy a known amount (in tonnes) of VOC emission (e.g. reducing the emission levels from 10 mg C/m<sup>3</sup> to 3 mg C/m<sup>3</sup> for a described waste gas flow). These can then be multiplied by the relevant marginal social cost and compared. Comparing the damages for CO<sub>2</sub> with those for VOC are simplistic: changes in NO<sub>x</sub> also need to be taken into account (if known). Also, the CO<sub>2</sub> contribution from the burnt VOC should be added in.

Recent data on a range of marginal social costs of climate change gives a central illustrative estimate of EUR 20 to EUR 25/t CO<sub>2</sub> for 2 000, rising to EUR 34/t CO<sub>2</sub> in 2020 (see Annex 21.8) [66, AEA, et al., 2005]. The EUA trading price of carbon was EUR 19 to EUR 23/t CO<sub>2</sub> during summer 2005 and down to EUR 15 during summer 2006. Most studies predict an EUA between EUR 5 and EUR 10/t CO<sub>2</sub> for the period 2005 to 2007, and between EUR 10 and 25/t CO<sub>2</sub> for the period 2008 to 2012.

Data from the cost benefit assessment for CAFE (see the ECM REF) give damages for VOC per tonne emission. The range of average values under different sets of assumptions for the EU-25 (without Cyprus) is EUR 950 to EUR 1 400/t emission. The lowest and highest values for individual countries range from EUR 140 to EUR 4 000/t emission. These are using a SOMO 35 approach with different sensitivities of the analysis. The countries vary in population density and differing low level ozone formation impacts so national or local figures could be used for individual installations.

When comparing these two sets of data, it is important to bear in mind that some impacts may be excluded and there are modelling assumptions and significant statistical uncertainties. Also, these figures are derived for estimating costs and benefits at a national, EU or international level, and may not transfer well to a calculation for an individual installation or take into account its local environmental quality standards.

On an EU level, a range of average VOC damages compared with a central bound of CO<sub>2</sub> costs gives a range of 32–140 tonnes of CO<sub>2</sub> to abate one tonne of VOC (40 000–175 000 m<sup>3</sup> of natural gas), see Table 17.7. However, these cost ratios give a cost of abatement of one tonne of VOC of between EUR 14 000 and EUR 63 000, which exceeds the marginal damage of VOC per tonne by 10 to 66 times (based on a cost of gas of EUR 7.52 to EUR 10.48 per GJ in 2006). Two countries (Belgium and the Netherlands) use cost benefit benchmarks of EUR 3 200 and EUR 4 500 (respectively) as the total cost per tonne of VOC abated. This would indicate that these comparisons significantly exceed the economic feasibility of burning this amount of gas on an EU-25 level. (It may be that the marginal social cost of CO<sub>2</sub> used is too low).

These values do not take into account any CO<sub>2</sub> any NO<sub>x</sub> impacts derived from oxidising VOCs.

Table 17.7: Comparison of marginal social costs of climate change with marginal damage costs from VOC emissions

Marginal social costs of climate change (EUR/t CO <sub>2</sub> )	Marginal damages for VOC (EUR/tonne emission)	Tonnes of CO <sub>2</sub> to abate 1 tonne VOCs	Thousand m <sup>3</sup> of natural gas to abate 1 tonne VOCs*
10	950	95	119
10	1400	140	175
20	950	48	60
20	1400	70	88
30	950	32	40
30	1400	46	58

\* Based on a density of natural gas of 0.8 kg/m<sup>3</sup> at STP.  
(See Annex 21.8.)

- Influence of limit value for CO:** the CO value out of the incinerator mainly depends on the combustion chamber, temperature and the residence time of the exhaust gas inside the combustion chamber. To lower levels for CO means the following:
  - Increasing the combustion chamber temperature (results in higher running costs). Usually it is enough to increase the combustion temperature to about 850 °C. At VOC concentrations near or above the autothermal point, this will be automatically achieved. The total influence on running and capital costs with regard to lower CO levels can be seen as negligible.
  - Increasing the combustion chamber size to have a longer residence time (results in higher investment costs).
- Balance between CO, NO<sub>x</sub> and VOC reduction:** no data submitted.
- Maintenance:** see Section 17.2.7.

#### Achieved environmental benefits

VOC and odour reductions can be achieved where there is waste gas treatment.

#### Cross-media effects

Energy consumption in air extraction systems can be significant. Energy consumed to reach low VOC concentrations can be significant. Noise can be a significant factor. Burning 40 000–175 000 m<sup>3</sup> of natural gas to destroy 1 tonne of VOC may not be sustainable.

#### Operational data

For data on individual techniques, see the relevant sections.

#### Applicability:

Generally applicable.

Cost-benefit of energy consumption to control low solvent emissions: Comparing the marginal social costs for CO<sub>2</sub> with those for VOC is currently over-simplistic. There are synergies as well as anti-synergistic effects between air pollution and greenhouse gas emissions. It is important to bear in mind that some impacts may be excluded (such as reducing CO<sub>2</sub> emissions may also reduce NO<sub>x</sub>, SO<sub>x</sub> and possibly PM<sub>2.5</sub>). This makes costs and benefits complex to allocate. There are also modelling assumptions and significant statistical uncertainties. Also, these figures are derived for estimating costs and benefits at a national, EU or international level, and may not transfer well to a calculation for an individual installation or take into account its local environmental quality standards.

#### Economics

See Applicability, above.

### Driving force for implementation

- Extraction: workplace health and safety.
- All considerations: odour, IED, national legislation.

### Example plants

No data submitted.

### Reference literature

[38, TWG, 2004] [50, COM, 2005] [78, TWG, 2005, 113, ECN, 2005] [66, AEA, et al., 2005, 114, AEA and Institute, 2005] [67, EIPPCB, 2003] [ec.europa.eu/environment/air/cafe/activities](http://ec.europa.eu/environment/air/cafe/activities)  
[www.engineeringtoolbox.com/gas-density-d\\_158.html](http://www.engineeringtoolbox.com/gas-density-d_158.html)  
Energy costs: Eurostat <http://epp.eurostat/ec.europa/eurostat>.

### System maintenance

*ESVOC propose deletion- Combined with 17.2.7*

**Description:** All waste gas systems need maintenance, both preventative and for breakdowns. Untreated emissions can be minimised by:

- planned maintenance (see Section 17.2.7). Where it is necessary to shut down key emission abatement equipment (and this may include some days for cooling before the equipment can be touched), the emissions can be minimised by carrying out maintenance:
  - during low or no production times (e.g. vacation shutdown periods)
  - during periods when emissions will have least impact, i.e. for VOC emissions, during periods of low sunlight levels, low probability of inversion layers, etc. This is dependent on weather, time of year and local conditions
- monitoring key equipment for problems such as vibration, emission leaks and planning repairs (as above)
- using decentralised/dedicated treatment systems so breakdown/repair only affects the systems in question (see Section 0)
- dealing with breakdowns and detected faults as rapidly as possible.

**Achieved environmental benefits:** Reduction in overall emission loads. Generally, defects in incineration equipment can give rise to VOC emissions equivalent to 0.4 % of the annual input per day, see Section **Error! Reference source not found.**

**Cross-media effects:** No data submitted.

**Operational data:** No data submitted.

**Applicability:** No data submitted.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [38, TWG, 2004].

### Bypassing peak emission flows (peak shaving)

*Proposed for deletion as the data is based on a virtual plant and no actual plants using the technique are identified. It relates more to the cost-benefit aspects of WGT plant design and no environmental benefit is identified.*

### Description

The maximum airflow of each dryer is designed to cope safely with the maximum amount of solvent input per unit of time that may need to be dried (for example in flexible packaging, 100 % coverage of substrate with a thick layer of varnish). The maximum airflow of the plant equals the sum of all the maximum airflows from each dryer. This is the theoretical capacity requirement of the incinerator (if there is no bypassing). However, the maximum airflow for the whole plant is very rarely achieved because (a) most dryers do not need to evacuate the maximum amount of solvent most of the operating time, and (b) machines are standing idle for significant periods (in flexpack, at full capacity, the machines are idle 50 % of the time). The result is that the last 20 % of an incinerator's theoretical capacity would hardly ever be used.

### Achieved environmental benefits

A significant reduction in energy consumption, and because the capacity of the abatement equipment needed is lower, smaller ventilators are needed and less additional fuel may be needed to run thermal abatement techniques.

### Cross-media effects

No data submitted.

### Operational data

Simulations were carried out at a virtual flexible packaging plant with a solvent input of approximately 1000 tonnes per year and a maximum airflow of 80 000 m<sup>3</sup>/h. Each step in **Error! Reference source not found.** shown below represents a change in capacity of 2 000 m<sup>3</sup>/h and a marginal additional investment of approximately EUR 20 000–30 000.

Table Emissions and costs in relation to incineration capacity

Incineration capacity as % of maximum airflow	kg solvent bypassed per year	Solvent bypassed as a % of plant solvent input	Marginal EUR/t for abatement
92.5–95.0	240	0.024	24 000
90.0–92.5	990	0.099	5 800
87.5–90.0	1 290	0.129	4 470
85.0–87.5	2 270	0.227	2 560
82.5–85.0	4 040	0.404	1 450
80.0–82.5	6 190	0.619	950
77.5–80.0	9 040	0.904	670

Source: [4, Intergraf and EGF, 1999]

### Applicability

This technique can be used in conjunction with peak/trough smoothed by adding low solvent concentration waste gas streams when the treatment capacity is under utilised, see Section 17.10.1.1.1.

Designing abatement equipment for less than the maximum waste gas flow is acceptable where it can be expected that the maximum load will be achieved very rarely in operation. In this case, the possibility for exceeding the operational maximum load (and going to bypass) can be minimised through a machine management system.

In addition, the untreated waste gases that occur in the case of bypassing must be taken into account in the solvent management plan as part of the total waste gas emissions. This technique may not be usable where waste gas emission limit values are applied, and therefore, the technique is likely only to be usable when using a reduction scheme.

### **Economics**

The ECM REF quotes average marginal damages (including health effects) per tonne of VOC emitted as ranging from EUR 950 to EUR 2 800 across the EU 25: costs will vary according to the location and individual calculations can be up to EUR 8 000 for individual countries.

~~On an annual basis, bypassing less than 1 % of the solvent emissions reduces the capacity need and thus savings on both investment and running costs by up to 50 %. It can be more cost-effective to reduce fugitive emissions by an extra few per cent than to design the abatement equipment for the full ventilation capacity.~~

### **Driving force for implementation**

Cost benefit and EMS, see Section 17.1.2.

### **Example plants**

No data submitted.

### **Reference literature**

[4, Intergraf and EGF, 1999] [18, UBA Germany, 2003] [38, TWG, 2004] [50, COM, 2005] [78, TWG, 2005]

#### **17.10.1.1 Dedicated/decentralised waste gas treatment systems for each point source**

##### **Description**

Each single printing or painting line can have a dedicated waste gas treatment system. For example, if it is integrated in the dryer(s), the system allows the heat of the waste gas to be easily used to heat up the air in the dryers.

The presses or coating line are not dependent on one central waste gas treatment system. For example, for publication gravure, the advantage of each press having its own dedicated waste gas adsorption system is that when the activated carbon bed needs to be cleaned, it only affects one press. Cleaning a central adsorption system often involves several presses.

##### **Achieved environmental benefits**

Compared to the common central waste gas treatment system, higher removal efficiencies can be achieved. This is possible because the capacity of the treatment system matches exactly what is required on the printing or painting line. Making adjustments to the plant, e.g. expanding the plant with an extra press or coating line is easier with dedicated treatment systems than with one central system.

When integrated in the dryer, this technique minimises calorific losses and thus energy consumption as waste heat can be used very efficiently.

The effects of breakdown or maintenance can be reduced, as (in printing and winding wire coating) the press or coater shuts down when the WGT is not functioning.

##### **Cross-media effects**

No data submitted.

##### **Operational data**

See Description, above.

##### **Applicability**

Applied in publication gravure printing plants. Also applicable in heatset offset printing processes, because one press has only one dryer which can be integrated with a thermal waste



gas treatment and the energy saving on the dryer may pay for the additional investment. In both cases, it is only applicable for new presses.

It is used as a standard technique in the automotive industry.

Not applied in packaging gravure printing plants, whose adsorption systems are centralised and have several absorbers. Each adsorber can be individually closed for maintenance without affecting emissions and the working of the press run.

Not applied in the coil coating industry.

### **Economics**

This technique is more expensive than a central waste gas treatment system; however, depending on the existing system, energy savings can be significant. Installing a dedicated waste gas treatment system to a new press is cheaper than expanding the existing treatment system.

### **Driving force for implementation**

No data submitted.

### **Example plants**

Volkswagen AG, Wolfsburg, Germany.

### **Reference literature**

[18, UBA Germany, 2003] [54, BMLFUW Austria, 2003] [13, DFIU and IFARE, 2002] [78, TWG, 2005]

## **17.10.1.1.2 Central waste gas treatment**

### **Description**

In flexible packaging, there is no advantage to dedicated waste gas treatment. Presses are equipped with 8 to 12 dryers and all dryers from different presses are normally routed to one central thermal treatment. The reason is that emission control equipment for individual presses must typically be situated on the roof immediately above the press. Limitations of the roof support strength prohibit the use of larger, heavier control equipment. A central gas treatment system, such as a regenerative thermal oxidiser, located adjacent to the building can be built with adequate size for greater residence times and superior thermal efficiencies.

Flexible packaging printing is also very much a batch process. Individual presses may be offline 30–50 % of the time for set-up and changeover. During this time of press inactivity, a press specific oxidiser must continue to burn fuel to maintain the temperature. Most central waste gas treatment systems use a variable frequency drive (see Section 17.10.3.1) to modulate the airflow to match the exhaust from any number of presses that may be in operation. Since the regenerative thermal oxidiser is only burning solvent-laden air, it can often sustain autothermal operation where no additional fuel is required.

### **Achieved environmental benefits**

No data submitted.

### **Cross-media effects**

No data submitted.

### **Operational data**

No data submitted.

### **Applicability**

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[18, UBA Germany, 2003] [54, BMLFUW Austria, 2003] [13, DFIU and IFARE, 2002] [38, TWG, 2004]

**17.10.1.2 Utilising WGT over-capacity to reduce VOC emissions– smoothing variations**

**Description**

Often referred to as peak/trough smoothing. Periodic diversion of air with a low VOC concentration (e.g. from the production hall extraction) to the WGT when the WGT has over-capacity.

**Technical description**

Existing waste gas treatment (e.g. incinerators) is generally not used to full capacity since more often than not, one of the surface treatment modules (press, spray booth, dryer, etc.) is idle or a number of dryers are not used. During this time, the excess capacity can be used for the local extraction. This needs extra ducting and a system that protects the incinerator from being overloaded through bypassing these low concentration airflows in the few cases where the full capacity is needed for the presses.

**Achieved environmental benefits**

Reduction of solvent emissions. Lower energy consumption than constant extraction.

**Cross-media effects**

The solvent concentrations in the resulting airflow need attention. They will be lower than before and may fall outside the incinerator's design range for autothermic operation and need additional fuel consumption.

**Operational data**

Implementation of the IED. Workplace health and safety. Control of exposure levels.

**Applicability**

~~No data submitted.~~

Only applicable to thermal treatment of off-gases in batch processes, such as printing

**Economics**

There is a cost of over EUR 100 000 to retrofit this system. Running costs are lower and additional capital costs (such as a larger incinerator) can be avoided.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[38, TWG, 2004]

**17.10.2 Containment and collection of waste gases**

This section describes the containment and collection of waste gases from coating applications and drying processes. The handling and storage of solvents is discussed in Section 17.2.2. The choice of collection and treatment systems is also discussed in the CWW BREF [67, EIPPCB, 2003].

**17.10.2.1 Air extraction at the point of application [Encapsulation/enclosure]****Description**

Air extraction at the point of application with full or partial enclosure of solvent application zones (e.g. coaters, application machines, spray booths, manual and machine cleaning) and subsequent treatment of extracted gases. This may be combined with extraction of the production hall air

Full or partial enclosure of solvent application zones (e.g. coaters, application machines, spray booths, manual and machine cleaning) combined with air extraction and subsequent treatment of extracted gases. This may be combined with extraction of the production hall air.

**Technical description****Achieved environmental benefits**

Reduces fugitive emissions and noise. Reduces volume of air to be extracted (and therefore energy used) and reduces size of, and energy used in, any waste gas treatment.

**Environmental performance and operational information**

Parts of the machinery or whole lines can be encapsulated/enclosed to avoid the release of fugitive emissions. Enclosure may also be for workplace health and safety, to reduce the risk of injuries from machinery or to reduce noise.

Air may be extracted from the application machinery used in the main process, such as printing presses, coil coating lines or automotive coating lines. The application equipment may be open (in reality, extraction is from the whole room: this is used in some industries for health and safety reasons) or partially or wholly enclosed. ~~The extracted air may be treated.~~

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Technical considerations relevant to applicability**

May not be applicable to existing units due to technical and space limitations.

Widely applicable for, e.g. publication gravure printing machines, flexo and gravure printing, textile coating, winding wires, coil coating. In flexible packaging, modern varnishing machines may be completely encapsulated and encapsulation ventilated by negative pressure dryers. All emissions are sent to an incinerator.

In coil coating plants, the emissions from process equipment, which are insignificant in comparison with the operation of the dryers, are vented directly to the air. Due to the high volume of airflow involved, large quantities of energy would be required to abate the air stream. The use of energy would exceed the environmental benefit that might be gained from the

abatement. The air from the dryers (and from coating in newer installations) are extracted and treated by thermal oxidation.

For the coating of large components such as aircraft bodies and ships, containment and extraction may be impracticable

**Economics**

No data submitted.

**Driving force for implementation**

Workplace health and safety.

**Example plants**

Widely used.

No data submitted.

**Reference literature**

[18, UBA Germany, 2003] [22, ECCA, 2004][38, TWG, 2004, 78, TWG, 2005]  
[76, TWG, 2004, 128, TWG, 2005].

**17.10.2.2 Air extraction and treatment from the production hall**

**Description**

Extraction and treatment of air from the production hall with solvent operations.

**Technical description**

**Achieved environmental benefits**

**Environmental performance and operational information**

**Cross-media effects**

**Technical considerations relevant to applicability**

May not be applicable to existing lines due to technical limitations and energy consumption considerations.

**Economics**

**Driving forces for implementation**

**Example plants**

**Reference literature**

**17.10.2.3 Enclosure of the paint/coating/ink preparation room**

**Description**

The ink/coating/paint preparation room (mixing area) is equipped with an air extraction system. Extracted air is treated at the abatement system.

**Achieved environmental benefits**

Reduces fugitive emissions.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability****Technical considerations relevant to applicability**

May not be applicable to existing lines due to technical limitations. Widely applicable.

**Economics**

No data submitted.

**Driving force for implementation**

Workplace health and safety.

**Example plants**

Widely applied.  
Seyntex, Tielt, BE.

**Reference literature**

[38, TWG, 2004, 78, TWG, 2005][179, COM 2017]

**17.10.2.4 Seals on the entrance and the exit of the ovens/dryers****~~Air seals on the entrance and the exit of the ovens/dryers~~**

See also Section 17.10.2.1.

**Description**

*TWG: please provide more information and examples.*

The entrance to and the exit from ovens/dryers is sealed. This may be by air jets or air knives, plastic curtains, doctor blades, plastic curtains, etc. Air jets or air knives at the entrance/exit of the ovens/dryers minimise fugitive emissions.

~~Air seals at the entrance and on the exit of the oven/dryer assist in the prevention of fugitive emissions.~~

**Achieved environmental benefits**

~~Reduction of fugitive emissions.~~

Minimisation of fugitive emissions and heat loss.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

Generally applicable. Commonly applied in the coil coating industry. Usually ~~require~~ applied with negative pressure/air extraction (see Sections 17.10.2.5 and 17.10.2.6).

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[22, ECCA, 2004], [38, TWG, 2004] [78, TWG, 2005]

**17.10.2.5 Negative pressure in drying**

*TWG is asked if this technique should remain or combined with technique in Section 17.10.2.6 (Air extraction from drying/curing processes)*

See also Section 17.10.2.6.

**Description**

Ovens/dryers are maintained at negative pressure to minimise the escape of VOCs. Typically, the volume of air injection is 70–75 % of the exhausted volume.

**Achieved environmental benefits**

Reduction of fugitive VOC emissions. Negative pressure causes air to flow into the oven and favours the capture of VOC vapours from the wet coating entering the oven.

**Cross-media effects**

No data submitted.

**Operational data**

Need of an extraction system.

**Applicability**

May not be applicable to existing lines due to technical limitations. Commonly applied in the coil coating industry.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [22, ECCA, 2004], [38, TWG, 2004]

**~~Air extraction from application zones / coating processes~~**

*Combined with Section 17.10.2.1*

**~~Description~~**

**~~Achieved environmental benefits~~**

**~~Cross-media effects~~**

**~~Operational data~~**

**~~Applicability~~**

**~~Economics~~**

**~~Driving force for implementation~~**

**~~Example plants~~**

**~~Reference literature~~**

### 17.10.2.6 Air extraction from drying/curing processes

#### Description

The dryers and ovens are equipped with air extraction system. Extracted air is treated in the abatement system.

~~The dryers and ovens are equipped with an air extraction system routing the solvent emissions to the waste gas treatment.~~

#### Achieved environmental benefits

Reduction of fugitive solvent emissions.

#### Cross-media effects

Extraction requires energy. Noise levels might increase.

#### Operational data

No data submitted.

#### Applicability

Generally applicable.

#### Economics

No data submitted.

#### Driving force for implementation

Workplace health and safety.

#### Example plants

No data submitted.

#### Reference literature

[18, UBA Germany, 2003] [22, ECCA, 2004] [38, TWG, 2004]

### 17.10.2.7 Air extraction from the cooling zone

#### Description

When substrate cooling takes place after drying/curing, the air from the cooling zone is extracted and treated.

~~After drying/curing, cooling may take place. The area where cooling is carried out may be enclosed. The waste gases containing solvent can be extracted and subsequently routed to abatement equipment.~~

#### Achieved environmental benefits

Reduced VOC emissions.

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

May not be applicable to existing lines due to technical limitations and energy consumption considerations. Commonly applied to coil coating installations (see Section 6.4.5.7).

#### Economics:

High costs are involved.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [22, ECCA, 2004], [38, TWG, 2004]

**17.10.2.8 Air extraction from storage of raw materials and wastes**

**Description**

Air from raw material stores and/or individual containers for raw materials, solvents and solvent-containing wastes is extracted and treated

**Technical description**

For safety reasons, new material stores, waste containing solvents, e.g. contaminated wipes and solvent-based residues stored in containers (see Section 17.2.2) may have an individual air extraction point(s). The extraction point should be set at a low level as the solvent vapours are heavier than air.

**Achieved environmental benefits**

Reduction of fugitive emissions if the waste gas is treated.

**Cross-media effects**

Noise levels might increase. Energy consumption for extraction increases.

**Operational data**

Commonly applied in publication gravure plants.

**Applicability**

May not be applicable to existing lines due to technical limitations and energy consumption considerations. Applicable in new and existing plants and all closed storage for wastes containing solvent, although whether the extracted air is fed to waste gas treatment will depend on the volume and concentration. The VOC concentrations are usually low.

**Economics**

The costs are low when compared to the total cost of the solvent recovery system. The savings for each kg of toluene recovered are about EUR 0.50. The extra capacity needed does, however, cost money. The cost per kg not emitted is high.

**Driving force for implementation**

Workplace health and safety.

**Example plants**

No data submitted.

**Reference literature**

[18, UBA Germany, 2003] [22, ECCA, 2004] [38, TWG, 2004] [78, TWG, 2005]



### 17.10.2.9 Air extraction from cleaning processes

#### Description

The areas where machine parts and equipment are cleaned, either by hand or automatically, equipped with an air extraction system routing the solvent emissions to the waste gas treatment.

#### Technical description

See Section 17.9, for in-machine cleaning see Section 17.10.2.1.

Technical details vary according to situation. For instance:

- for regular cleaning, e.g. of pumps used for transferring coatings (see figure ) cleaned by pumping through clean solvent, an area may be enclosed, with air extraction;
- it may be possible to relocate hand cleaning to an area that is enclosed and extracted, e.g. paint mixing.

#### Achieved environmental benefits

Reduction of fugitive solvent emissions.

#### Environmental performance and operational information

Noise levels might increase.

#### Cross-media effects

Extraction systems require energy.

#### Technical considerations relevant to applicability

May not be applicable to existing lines due to technical limitations and energy consumption considerations. Enclosure and extraction with treatment depends on the amount and type of cleaning and the amount of solvent used. Space required for an enclosed area and capacity in the WG extraction and treatment may also be a limiting factor.

Machinery for cleaning may be used infrequently and at irregular intervals. Connecting them to abatement equipment may require extra capacity that is rarely used.

Cleaning by hand leads to very low solvent concentration and extraction may be needed to stay way below the OEL. It is not usually practical to send this low concentration waste gas to an incinerator.

~~Cleaning automatically: ventilation of washing machines is required before opening the machine. There are very high concentrations, but during a short time. It is usually practical to send to an incinerator, especially at times when the waste gas treatment is not in full use. This is used in package printing plants because they are normally equipped with a waste gas treatment system. See Section 17.9.~~

Not applicable in the winding wire industry because of the high boiling point of the solvents in the enamel.

#### Economics

Costs will depend on the existing extraction system and on the capacity of the waste gas treatment technique. Retrofit might, therefore, be very expensive. However, small incinerators could be fitted to automatic washing machines.

#### Driving force for implementation

Workplace health and safety.

#### Example plants

Seyntex, Tielt, BE

**Reference literature**

[18, UBA Germany, 2003] [22, ECCA, 2004] [38, TWG, 2004] [78, TWG, 2005]

**17.10.3 Maintaining VOC concentration prior to treatment**

**Pretreatment, filtration and scrubbing**

**17.10.3.1 Maintaining VOC concentration to treatment by variable frequency drives**

**Description**

Use of a variable frequency drive fan in centralised off-gas treatment systems to modulate the airflow to match the exhaust from the equipment that may be in operation.

Most central waste gas treatment systems use a variable frequency drive fan to modulate the airflow to match the exhaust from the equipment that may be in operation.

**Achieved environmental benefits**

Reduction of solvent emissions while minimising energy consumption for extraction and combustion support.

**Cross-media effects**

None.

**Operational data**

No data submitted.

**Applicability**

Only applicable to central thermal WGT in batch processes such as printing.

Flexible packaging printing is a batch process. Individual presses may be offline 30–50 % of the time for set-up and changeover. ~~During this time of press inactivity, if an oxidiser dedicated to one press is used, it must continue to burn fuel to maintain the temperature.~~

This is particularly important for regenerative thermal oxidisers, so only solvent-laden air is burnt and often autothermal operation can be sustained where no additional fuel is required.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[38, TWG, 2004]

**17.10.3.2 Increase of the internal solvent concentration**

**Description**

Off-gas is recirculated within the process (internally) in the dryers and/or in spray booths, so the VOC concentration in the off-gas increases and increases the abatement efficiency of the WGT.

**Technical description**

Allowing the solvent-laden air to circulate in the dryers or in spray booths (after sufficient particle separation and dehumidification) will increase the solvent concentration in the air and subsequently increase the solvent reduction efficiency of the waste gas treatment system. This can also be called 'internal concentration'.

The reduction of the airflow is limited by the need to avoid risks of fire and explosions: the smaller the airflow, the higher the solvent concentration and thus the greater the danger of fire and explosions. A prerequisite for applying this technique in dryers is, therefore, the installation of a lower explosion limit control to assure that the ventilation rate in the dryers is designed in such a way that the maximum solvent concentrations that can possibly occur does not exceed a certain percentage of the LEL of the solvents concerned.

Table 17.8 shows the LEL that are considered safe in flexible packaging printing.

**Table 17.8: Maximum allowable levels of LEL in the dryers in flexible packaging printing**

Situation	Maximum % LEL
Dryers heated by open flame or electricity	25
Dryers heated by open flame or electricity with extensive safety features	50
Dryers heated by thermal oil or steam	50

*Source: [4, Intergraf and EGF, 1999]*

Apart from internal concentration, 'external' concentration is also possible by applying, for example, an adsorption step prior to incineration; see Section 17.10.6.3.

**Achieved environmental benefits:** In flexo or packaging gravure plants, where no measures have been taken to reduce the airflow from the dryers, the average solvent concentration in the waste air may be no more than 1–2 g/m<sup>3</sup>.

#### **Environmental performance and operational information**

For solvents like ethanol, ethyl acetate or MEK, the LEL at the relevant operating temperatures is somewhere near 50 g/m<sup>3</sup>. A level of 25 % LEL will be some 10 g/m<sup>3</sup> or 12 g/m<sup>3</sup>. This will be the maximum concentration in each individual dryer, and this concentration cannot be reached in all the dryers at the same time. Where measures have been taken to reduce the airflow, the average solvent concentration can rise to 4–6 g/m<sup>3</sup>. These levels allow regenerative incineration without the extra addition of fuel.

Reduced energy input at lower temperatures as the air has already been heated and retains residual heat, therefore recirculated air requires less energy to reach the optimum (booth) air temperature.

Where the cost of the abatement equipment is not an issue, large safety margins are often employed. These, however, need to be re-evaluated when an investment in abatement equipment is necessary. The safety margin determines the maximum airflow and, therefore, the minimum size of the abatement equipment.

It is reported that recirculation without active LEL control can be carried out. The maximum recirculation allowed depends on safety regulations. Often 25 % LEL is allowed when heating is done by steam or thermal oil. Where heating is electric or by open flame, the rules may be stricter.

In the automotive industry, higher recirculation can be achieved in water-based paint shops as lower solvent content means occupational exposure limit (in manual booths) or explosive limit (in automated booths) takes longer to reach. However, recirculation can be restricted by the

tighter operating parameters required in the water-based spray booth for temperature and humidity.

#### **Cross-media effects**

No data submitted.

#### **Technical considerations relevant to applicability**

Applicability may be limited by health and safety factors such as the LEL.

In situations where low solvent concentrations are combined with a large exhaust airflow rate, a certain solvent concentration is necessary for economic treatment. Increasing the solvent concentration in the airflow is applicable to conventional dryers and to spray booths.

For dryers, this technique is commonly applied in the printing processes publication gravure (for improving the toluene recovery), flexography and packaging gravure, and in the automotive industry. In publication gravure, new presses have such large airflows that expanding existing recovery installations is not economical. Also, permits for new presses tend to have stricter ELVs, which add to the difficulty of expanding existing recovery installations.

It is commonly applied in the manufacturing of abrasives, where the maximum speed of the production line is at 50 % LEL of the substance with the lowest inflammation point: the line speed is electronically controlled to this level.

#### **Economics**

The cost of increasing solvent concentrations and reducing the airflow depends not only on the age and build of the presses, but also the size of the reduction which is achieved. Where end-of-pipe abatement is to be installed, it is generally wise to reduce the airflow until the marginal cost of further reductions become equal to the marginal cost of the additional capacity of the abatement equipment. For incinerators applied in printing plants, this is approximately EUR 10–15 per m<sup>3</sup>/h.

Reduction of the airflow also reduces energy consumption. As less air is used, less needs to be heated. In situations where the drying temperatures are low (40–60 °C), these savings in themselves do not generally warrant the investment.

#### **Driving force for implementation**

Lower capital investment, lower running costs of abatement equipment, including lower energy requirements.

#### **Example plants**

Ford plants in Europe. All modern packaging gravure presses.

#### **Reference literature**

[18, UBA Germany, 2003] [4, Intergraf and EGF, 1999] [12, UBA Germany, 2002] [13, DFIU and IFARE, 2002] [68, ACEA, 2004] [38, TWG, 2004] [78, TWG, 2005]

### **17.10.3.3 Increase of the external solvent concentration**

#### **Description**

The concentration of solvent in off-gas can be increased by a continuous circular flow of the spray booth or dryer off-gas through adsorption equipment. This equipment can include:

- fixed bed adsorber with activated carbon or zeolite polymers;
- fluidised bed adsorber with activated carbon;
- rotor adsorber (concentrator wheel) with activated carbon.

#### **Technical description**

**Achieved environmental benefits**

A transmission of the solvent load into an external hot air stream in the ratio 1:6 to 1:30 (depending upon the raw gas concentration) is achieved. A comparatively small waste gas flowrate can be economically disposed of via incineration or condensation for reuse, for example, as a cleaning solvent.

**Environmental performance and operational information**

In the automotive industry, the air stream must be treated prior to the adsorption phase to remove particulate matter; otherwise the function of adsorption would be affected. A level below the 1–3 mg/m<sup>3</sup> is necessary, which can be done by a number of techniques including:

- wet electrostatic precipitation;
- high-pressure venturi;
- cassette filters.

**Cross-media effects**

Increased energy use.

**Applicability**

This is not applicable where concentrations are high enough for autothermic incineration. This technique is only used where the cost of increasing the concentration and reducing airflow is less than the cost of additional treatment capacity.

It is usually applied where huge airflows with very low concentrations need to be treated (e.g. 250 000 m<sup>3</sup>/h with 0.25 g/m<sup>3</sup>), and even at these flows, the cost-benefit is not certain, as there are increased operational costs (for fans, heating and cooling, etc.).

It is also limited to certain kinds of solvents. They must release from the zeolite to the carbon at reasonably low temperatures otherwise they clog the carbon and reduce its lifespan.

In the automotive industry this technique is commonly used for waste gas from solvent-based spray booths. It can be used in water-based spray booths, but this is usually uneconomical due to the reduced solvent content of the airflow.

This technique is also commonly applied in adhesive manufacturing.

Rotor adsorbers (concentrator wheels) with activated carbon or zeolite polymers experience a dramatic reduction in effectiveness when the solvent gas temperatures exceed 38 °C. Dryers on presses producing flexible packaging have typically exhaust waste gases with temperatures exceeding 38 °C. This makes rotor concentrators a poor choice for the flexible packaging industry. Not used in publication gravure, heatset and flexible packaging printing.

**Economics**

The cost of concentrating solvent for reuse versus buying in material means that this application is implemented dependent on local cost conditions and the price of buying virgin material.

**Driving force for implementation**

Reduced VOC emissions and possibility of reuse of the waste gas.

**Example plants**

Ford plants in Europe.

**Reference literature**

[68, ACEA, 2004] [38, TWG, 2004] [78, TWG, 2005].

### 17.10.3.4 Plenum technique to increase VOC concentration and reduce waste gas volume

#### Increasing the external air concentration using a plenum

#### Description

Off-gases from dryers are sent to a large chamber (plenum), and partly recirculated as inlet air in the dryers. The surplus air from the plenum is sent to WGT. This cycle increases the VOC content of the dryers' air and decreases the waste gas volume.

#### Technical description

Plenum is defined as an air-filled space in a structure that receives air from a blower for distribution (as in a ventilation system). In this technique, it is the key part of a system for the external recirculation of air from dryers in order to increase the solvent concentration and reduce the net air volume to be treated by an abatement technique. See Figure 17.7.

Exhaust air from several dryers, often from several different coating machines, is sent to one large chamber – the plenum. The dryers take a large percentage of their inlet air from this chamber. The dryers supplement their inlet air from the surroundings of the coating machine. Thus, more air will be sent to the plenum than will be taken from it by the dryers. The excess air from the plenum is sent to an end-of-pipe abatement technique.

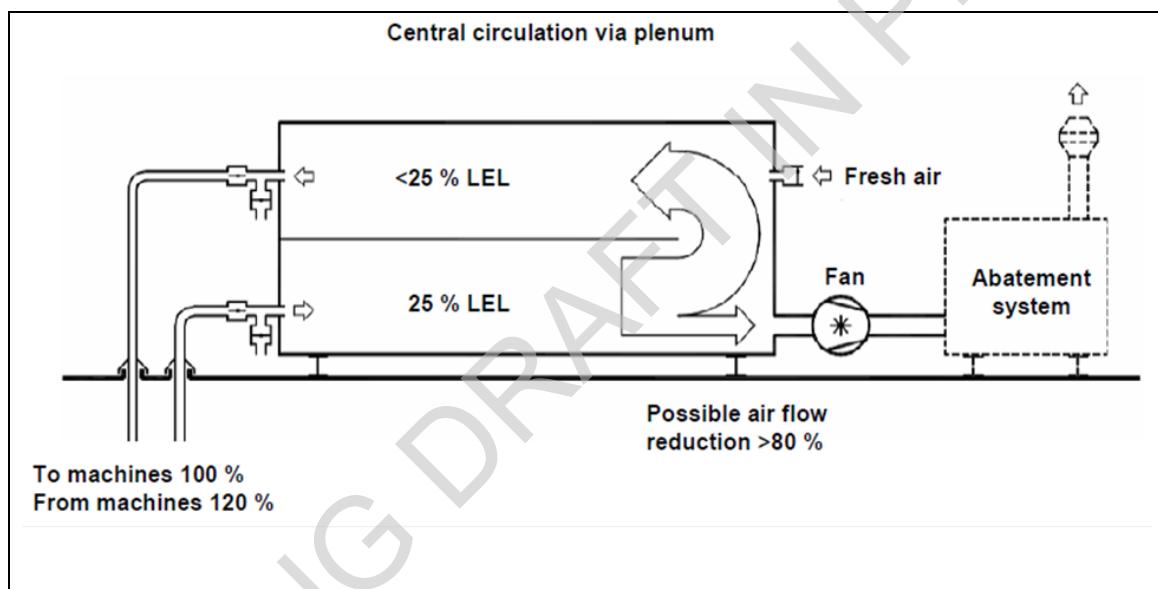


Figure 17.16: Plenum chamber

The solvent concentration in the plenum is constantly measured. The concentration in the air extracted from the plenum by the dryers is allowed to rise to close to 25 % LEL. The dryers take sufficient fresh air from their surroundings that in their exhaust the concentration will not exceed 25 % LEL. When the concentration in the plenum gets too high for this purpose, more air is extracted from it and the air volume in the plenum is supplemented with fresh air.

The plenum is an alternative to internal air recirculation in dryers.

#### Achieved environmental benefits

The net air volume to be treated by the abatement technique is very much reduced. Autothermic operation of the abatement technique becomes possible. Energy recovery from incineration becomes possible.

Energy is also saved because the net amount of air to be heated in the dryers is reduced to the amount taken from their surroundings.

### **Environmental performance and operational information**

Where dryers are applied without any internal recirculation and otherwise the outlet solvent concentration would be no more than one or two grams per m<sup>3</sup>, the net airflow to be treated by the abatement technique may be reduced by up to 80 %.

### **Cross-media effects**

No information provided.

### **Applicability**

Applicable in situations where low solvent concentrations in outlet dryer air occur and internal recirculation of dryer air is not technically possible or disproportionately expensive due to the large number of dryers in the plant. Such situations may, for instance, occur where several older flexographic or gravure presses are used with eight or more dryers each.

The inlet temperature of all the dryers will be the same. This may cause difficulties when some dryers require high temperatures and others not.

### **Economics**

The plenum is not a cheap technique. Where internal recirculation in the dryers is possible and the number of dryers is limited, the net cost of internal recirculation combined with a larger oxidiser may be cheaper.

### **Driving force for implementation**

Where applicable (see above) and economically advantageous compared with alternatives.

### **Example plants**

LPF, Leeuwarden, the Netherlands.

### **Reference literature**

[115, Verspoor and Sitmae Consultancy, 2005]

### **Membrane filtration**

#### **ESVOC propose deletion**

**Description:** This is a concentration technique, where the VOC rich gas is passed through an organic selective membrane module.

**Achieved environmental benefits:** The VOCs in the VOC rich permeate can be recovered, e.g. by applying condensation (see Section 17.10.6.1) or adsorption (see Section 0).

**Cross-media effects:** Energy is required for filtering. Retentate arises that needs to be disposed of eventually after further treatment.

**Operational data:** No data submitted.

**Applicability:** Membranes work better on specific molecules.

The technique is not applied in the winding wire industry, because the solvents cannot be re-used in the process. Not applied in the metal packaging or the automotive industries.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [24, ESIG, 2000] [38, TWG, 2004]

## 17.10.4 Dust abatement

### 17.10.4.1 Wet separation spray booth (flushed impact panel)

#### Description

A water curtain cascading vertically down the spray cabin rear panel captures paint particles from over-spray. The water-paint mixture is captured in a reservoir and the water recirculated.

#### Technical description

Overspray in a spray booth where surfaces are sprayed with paint materials can be intercepted by applying a water curtain. The water-paint mixture is captured and treated in a reservoir below the spray booth. ~~For waste water treatment, see Section 17.11.~~

~~Waste water is normally treated cleaned by applying flocculation and coagulation. The water is led across cascades or circulated via air introduction.~~

#### Environmental performance and operational information

Removal of TPM (total particulate material). Efficiencies of 98–99 % can be achieved. Sometimes the paint can be reused.

#### Cross-media effects

Residual waste water which can often be reused or is treated and discharged, and contaminated sludge that has to be disposed of.

#### Technical considerations relevant to applicability

Generally applicable. There may be technical and economic restrictions for retrofitting existing plants.

Wet separation spray booths are applicable to water- and solvent-based paints. They are common practice in:

- wood and furniture painting;
- the automotive industry;
- coating of aircraft components;
- coating of trains;
- coating of trucks and commercial vehicles.

#### Economics

Estimated costs for an installation with a capacity to withhold 2–5 m<sup>3</sup>/h waste water and covering a floor surface area of about 4 m<sup>2</sup> is about EUR 20000 or EUR 1–2 per Nm<sup>3</sup>. This size of installation is suitable for large spraying zones with several water curtains.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

[13, DFIU and IFARE, 2002] [27, VITO, 2003] [38, TWG, 2004]

~~Figure Scheme of waste water treatment applied in a wet separation spray booth [27, VITO, 2003] with reference to Kluthe Benelux BV~~



### 17.10.4.2 Wet scrubbing

#### Description

Wet scrubbing is a mass transfer between a soluble gas or dust and a solvent – often water – in contact with each other. For VOC removal, see Section 17.10.6.4.

Paint particles in the waste gas are separated in ~~airflowed scrubber collectors~~ scrubber systems by intensive mixing of waste air with water. ~~Water scrubbers may also be used to remove dust and other contaminants such as NO<sub>x</sub>.~~

In the automobile industry, a special type of scrubber called a venturi scrubber (based on the venturi principle) is used, see Section 17.10.4.3, below.

~~to obtain an excellent mixture of the particulates with the water. It is used without any other pretreatment for the separation of paint overspray from effluent air.~~

#### Achieved environmental benefits

Reduced particulate emissions to air. In an airflowed scrubber, the paint particles are separated to around 90 % (after the primary separation described in Section 17.10.4.1).

#### Cross-media effects

Filtering requires energy and might generate noise, waste and waste water.

#### Operational data

With the spraying of paint, normally an overspray arises which might need to be captured and treated. Scrubbers are normally applied as a secondary separation step after the venturi system described in Section 17.10.4.1. The scrubber might subsequently serve as a pretreatment for increasing the solvent concentration (see Section 17.10.3.3). The remaining particle content depends on whether the cleaned waste gas of the spray booth is directly supplied to a waste gas cleaning installation. For post-separation of paint particles after venturi washers, additional paint particle separators can become necessary. In particular, if a circulating airflow aimed at solvent recovery exists or a protection of subsequent installation parts (rotor, heat exchanger) is required, secondary separation methods are applied.

**Applicability** ~~See Description, above.~~

Generally applicable to both water-based and solvent-based paints.

~~Not applied in the winding wire industry.~~

#### Economics

Capital cost: EUR 2 000 up to EUR 30 000 per 1 000 Nm<sup>3</sup>/h (scrubber with recirculation pump); cost is strongly dependent on the application, e.g. type of impurities in the gases.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

[13, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005] [94, VITO, 2004]

### 17.10.4.3 Venturi scrubber particle separation

#### Description

Separation of paint particles (overspray) from paint booth exhaust air using a venturi system with circulating water.

### Technical description

The waste gas from the application zone contains paint particles. This air is carried into a venturi scrubber below the spray booth. In the venturi scrubber water droplets are separated from a water curtain. The water droplets combine with the paint particles, so that these heavier particles are deposited in the water.

Water and thin sludge are continuously drawn off from the circulation and are coagulated.

### Achieved environmental benefits

Reduced particulate emissions to air. In a venturi scrubber, the paint particles are separated to around 99 % and a remaining particle content of  $< 3 \text{ mg/m}^3$ .

### Environmental performance and operational information

With spraying of paint, an overspray normally arises which may need to be captured and treated. This separation is necessary in order to ensure a safe operation of the entire plant, to allow air circulation and to meet working and environmental legal requirements.

Due to the energy expenditure for air conditioning, air recirculation of e.g. 80 % is uneconomical and has not been established for health reasons.

### Cross-media effects

Filtering requires energy and might generate noise, waste (paint sludge) and waste water.

### Technical considerations relevant to applicability

Generally applicable in high throughput paint shops, such as vehicle coating.

### Economics

No information provided.

### Driving force for implementation

### Example plants

In all VW paint shops in Europe built before 2008.

### Reference literature

[5, DFIU and IFARE, 2002] [68, ACEA, 2004] [38, TWG, 2004] [78, TWG, 2005] [94, VITO, 2004] [VDI 3455]

~~**Description:** The waste gas containing paint particles is accelerated with water droplets using a venturi system. Intensive mixing takes place, followed by separation of the heavier particles. If water-based paint is applied, the separated paint can be reused.~~

~~**Achieved environmental benefits:** A particle separation of over 99 % is reached and a remaining particle content of  $< 3 \text{ mg/m}^3$  (for new scrubbers) and  $< 5 \text{ mg/m}^3$  (for conventional lateral scrubbers) in the waste air are achievable (see Section 17.10.4.1).~~

~~The efficiency for the recycling of overspray is in the range of 50–90 %, depending on the type of paint processed.~~

~~**Cross-media effects:** Noise levels might increase. The water droplets result in a waste water fraction.~~

~~**Operational data:** With spraying of paint, an overspray normally arises which may need to be captured and treated. Venturi systems are normally applied as a primary separation step of paint materials. This primary separation is necessary in order to ensure a safe operation of the entire plant, to allow air recirculation and to meet working and environmental legal requirements.~~

**Applicability:** ~~Venturi systems are normally applied as a primary separation step of paint materials.~~

~~Not applied in the winding wire industry as separation is not necessary and reuse is not possible. Also not applied in vehicle paint shops.~~

~~Venturi techniques are also efficient methods for reducing dust.~~

**Economics:** ~~No data submitted.~~

**Driving force for implementation:** ~~Reduction in particulate emissions to the air.~~

**Example plants:** ~~No data submitted.~~

**Reference literature:** [13, DFIU and IFARE, 2002] [68, ACEA, 2004] [38, TWG, 2004]

#### 17.10.4.4 Dry overspray separation with pre-coated material

*ACEA: Draft 1: Based on experiences with filtering systems from one supplier (Dürr). Similar systems or offered by other suppliers. These are typically used in non-vehicle paint shops (ACE, coating of other metal or plastic surfaces. Operational experiences will be provided via ESVOC in the next round.*

##### Description

A dry paint overspray separation process using membrane filters combined with limestone as pre-coating material to prevent fouling of the membranes.

##### Technical description

Waterless overspray removal in industrial spray booth using membrane filters coated with limestone. This prevents direct contact of the sticky wet overspray particles with the filter surface and the inside of the filter module.

At the beginning of a filtration cycle fresh limestone pre-coat material is introduced into the hopper. Air nozzles blow the dry material up into the air flow coming from the spray cabin. The limestone passes through the filter modules in circular channels and ensures circulation across all filter elements. Pre-coat particles in the air stick to the filter surface and module as a closed, thin protection layer. This prevents direct contact of the sticky wet overspray particles with the filter surface and inside the filter module.

*See Figure 1?*

##### Regenerative filter elements

The process-optimised, automatically regenerated filter, covered by a membrane layer, provides particle filtration of below  $0.1 \text{ mg/m}^3$ . This close to 100 % filtration process permits direct recirculation to spray booths without the requirement of additional filter levels. This filtration process takes place on the surface of the filter element, allowing direct recirculation of the clean air in the circulation process, as no pre-coat or paint particles get through the filter membrane.

##### Fully automated cleaning process

During paint application, separation of the paint particles takes place on the filter via the air circulation. The paint particles accumulate on the pre-coat material and build up a filter cake. This results in an increase in air resistance over the filter. Once a maximum decrease in differential pressure occurs, automatic blowing-off of the filter cake is triggered. A jet of compressed air from the clean gas side of the filter element is shot for approximately 0.25 seconds resulting in cleaning. Cleaning of the filter module is timely offset and takes place approximately every 25 minutes. The mixture of pre-coat and paint material falls to the bottom

of the hopper and stays there until a certain saturation point is reached. Once this saturation point has been reached the used pre-coat material is removed and replaced by new material.

Pre-coat material

The pre-coat material used is a natural limestone.

### Environmental performance and operational information

Compared to standard wet scrubber systems:

- Reduction of water consumption.
- Significant reduction of energy consumption and CO<sub>2</sub> emission (no need to dry the air used).
- Significant reduction of particulate emissions.
- No dependence to weather conditions.

Compared to standard wet scrubber systems:

**NOTE: (ACEA has asked members to provide reliable data. We will present results asap)**

as range figures (xx to yy) together with a list of installation which provided these data

Energy consumption (and related CO<sub>2</sub> emissions) and dust emissions:

- Reduction of XX to YY % of energy consumption.
- Reduction of xx to yy % of particle emission concentrations.

This is caused by:

- Direct recirculation of process air.
- Reduction of air supply housing due to reduced air treatment.
- No heat recovery.

Other resource considerations :

- Clean process (see below, no waste water, reduction of particulates emission):
  - Reduction of water consumption and waste water: No water required for overspray separation.
  - Reduction of xx to yy % water consumption for air conditioning.
- Reduction in hazardous chemicals usage:
  - No detackifier chemicals or biocides to stabilise wet scrubber water systems.
- Waste management:
  - Waste generation directly proportional to production.
  - Waste generated validated as non-hazardous waste.
  - No disposal of paint sludge with solvent residues.
  - Waste reused in cement clinker plants.

### Cross-media effects

- Consumption of natural raw materials (limestone).
- Generation of a new type of waste, in industrial quantities.
- Increase of truck road traffic.
- Increase of plastic foils waste (to protect inner surfaces of the spray booth and baffle plates).

### Technical considerations relevant to applicability

May be implemented in existing installation, either using solvent- or water-based paints, depending on installation layout. No significant modification (similar dimension, no process modification). Modular construction means this can be applied to airflows from A –B '000m<sup>3</sup>/h per module.

- High reliability process but needs skilled operators.
- Not applicable in combination with air recycling in spray booths with manual painting process.

- Not applicable in installations with low production capacity (below 15 car/h), or for two tones painting.
- Outdoor capacity to implement CaCO<sub>3</sub> storage must be available next to the paint booth.
- Only limestone with approved qualities can be used, any derogation might have negative effects on the filtration efficiency and the lifetime of the filter material.
- Quality and cost of filter used.

It is also applied in several plastic parts paint shops (e.g. automotive bumpers)

### **Economics**

Difference in investment with water scrubber is compensated after less than one year, depending on the installation (similar invest and maintenance cumulated costs for both solutions, but economy in running costs).

### **Driving force for implementation**

- Lower maintenance effort.
- Simple, fully automated system.
- Long filter replacement cycle (lifetime proven beyond three years).

### **Example plants**

This system is widely used in more than 30 new vehicle paint shops worldwide:

Europe:

2008 onwards, at least 10 passenger car plants and 4 commercial vehicle plants (see plants in data collection. Not confirmed how we present these yet).

USA:

2011 onwards, at least 6 passenger car plants.

China:

Since 2011, at least 18 passenger car plants.

It is also applied in several plastic parts paint shops (e.g. automotive bumpers).

### **Reference literature**

**NOTE: References in English will be added asap**

Krug, Henner (2004): Neuer Trockenabscheider für Class-A-Beschichtungen. In: JOT 44 (7), S. 16–17. DOI: 10.1007/BF03240868.

KELLER (Fa) (2014): RECLAIM Trockenabscheidung. Die hocheffiziente, vollautomatisierte Filtertechnik für das Nasslackieren. Produktbeschreibung, zuletzt geprüft am 19.08.2016.

Hajek, Stefan (2007): Wartungsarme Trockenabscheidung. Abluftreinigung mit Trockenfilter. In: JOT (3), S. 42–43.

KELLER (Fa) (2016): Generalprobe für Overspray-Absaugung. Baumaschinenhersteller modernisiert Lackieranlage. In: J Oberfl Techn 56 (8), S. 36–37, zuletzt geprüft am 20.08.2016. [ACEA 2017]

#### **17.10.4.5 Dry overspray separation using cardboard box (labyrinth) filters**

**Needs editing + more data**

### **Description**

Mechanical dry separation system using cardboard box modules in a labyrinthine flow path.

### **Technical description**

Dry separation using cardboard box is a mechanical separation system. Air contaminated with paint particles during spraying is pulled into the separation system, which is made of several modules.

The separation modules are hybrid filters, consisting of surface and depth-type filters. Individual filter elements are arranged in such a way as to create a labyrinthine flow path. This configuration ensures an even distribution of particles in the separation module.

### **Environmental performance and operational information**

The filters can be made mostly from recycled materials and be folded during storage and delivery. No chemicals, water or additives are required.

Spent modules can be used as a fuel source via incineration.

### **Cross-media effects**

#### **Technical considerations relevant to applicability**

Applied in metal and plastic parts coating.

First applications in low capacity passenger car and commercial vehicle paint shops (< 5 sites).

### **Economics**

#### **Driving force for implementation**

#### **Example plants**

Widely applied.

#### **Reference literature**

[http://www.durr-france.com/fileadmin/user\\_upload/fas/02\\_psa/pdf\\_e/EcoDryScrubber\\_Brochure\\_LowResolution\\_EN.pdf](http://www.durr-france.com/fileadmin/user_upload/fas/02_psa/pdf_e/EcoDryScrubber_Brochure_LowResolution_EN.pdf)  
[ACEA 2017]

### **17.10.4.6 Electrostatic filter (precipitator)**

#### **Description**

In electrostatic precipitators, particles are charged and separated under the influence of an electrical field. In a dry ESP, the collected material is mechanically removed (e.g. by shaking, vibration, compressed air). A wet ESP (e.g. e-scrub) it is flushed with a suitable liquid, usually water, see Section 2.4.8.2.

~~Electrostatic filters (precipitators) are used to eliminate particles from the waste gas. Particles are charged within an electrostatic field and migrate towards condensation plates. The particles are removed: in wet systems, this is by washing with water~~

#### **Achieved environmental benefits**

No data submitted.

#### **Cross-media effects**

Noise levels might increase. With wet electrostatic filters, there is the production of a wet waste, and waste water which may require treatment.

#### **Operational data**

With the spraying of paint, an overspray normally arises which might need to be captured and treated. Electrostatic filters are normally applied as a secondary separation step after the venturi system described in Section 17.10.4.1. The electrostatic filter might serve as pretreatment for the solvent concentration (see Section 17.10.3.3).

#### **Applicability**

No data submitted on actual use.

~~It is not~~ Applied in the automotive industry (E-scrub, see Section 2.4.8.2) ,

Not applied in the manufacturing of abrasives or in the coating of ship and aircraft components.

### **Economics**

In general, there is a higher installation cost associated with electrostatic precipitators than for dry filters, but the operating cost is lower.

Installation/investment cost: EUR 60 to EUR 300 for systems of 30 000–200 000 Nm<sup>3</sup>/h. Operational costs: EUR 0.05 to 0.1 per 1000 Nm<sup>3</sup>/h for systems bigger than 50 000 Nm<sup>3</sup>/h. Additional costs and environmental impacts for removing the sludge, energy costs (0.17–0.35 kWh/Nm<sup>3</sup>) for the basic installation, and the ventilator fan consumes an additional 0.17–0.5 kWh/Nm<sup>3</sup> published in 2004).

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

### **Reference literature**

[13, DFIU and IFARE, 2002] [67, EIPPCB, 2003, 68, ACEA, 2004] [38, TWG, 2004] [95, CEI-BOIS, 2006] [94, VITO, 2004]

### **Dry particle filter systems**

*Replaced by Sections 17.10.4.4 and 0*

### **Pre-coated particle filter**

*Replaced by Section 17.10.4.4*

### **Paint-in-paint spray booth**

[This technique has been removed]

*ESVOC propose deletion*

### **Water emulsion techniques**

*ESVOC propose deletion*

### **Cold plate spray booths**

*ESVOC propose deletion*

## **17.10.5 Oxidation**

Annex 21.9 provides a summary of waste gas treatment techniques (oxidation, adsorption, condensation and biological treatment) and their applicability. A comparison of the removal efficiencies of the most widely used techniques is given for different types of solvents at different inlet concentrations [97, TWG, 2006].

When natural gas is used as additional fuel, emissions of unburnt CH<sub>4</sub> can occur that are normally below 50 mg/m<sup>3</sup>.

If the solvent mixture contains elements other than H, C or O, hazardous, toxic and/or corrosive by-products may be formed. Solvents containing halogenated compounds form aggressive flue-gases. When these flue-gases contain nitrogen, they form NO<sub>x</sub> and when they contain sulphur, they form SO<sub>x</sub>. Oxidation of ducting and vents may occur.

### 17.10.5.1 Fuel supplement in process heating

*ESVOC propose deletion. Used in some plants responding to data collection.*

#### Description

The ~~waste gas~~ off-gas ~~to be treated~~ is sent to an existing heater (e.g. boiler) as combustion air and complementary fuel.

#### Achieved environmental benefits

Solvent emissions are treated and the emissions of the boiler will not change because solvents are used instead of fuel.

#### Cross-media effects

No data submitted.

#### Operational data

The prerequisite for using an existing boiler is that it must be operational and able to receive vapours at all times when vapours are produced. Boilers usually work continuously, but the solvent load can be discontinuous. Low levels can be achieved for halogenated solvents where required; however, lower VOC levels may require additional fuel.

The concentration range of the inlet gas is only limited because of the maximum LEL values and the airflow range that can be treated depends on the capacity of the existing boiler.

This technique can treat all types of solvents and solvent mixtures and no specific pre- or post-treatment is needed; however, it is common practice to apply a proper CO control.

#### Applicability

Generally applicable. This technique is easy to apply and is most appropriate for existing boilers with sufficient capacity and for production processes with a high energy demand.

Not applied to halogenated solvents containing sulphur or nitrogen or other hazardous solvents (See Cross-media effects, above).

It is not applied in the winding wire industry, in vehicle paint shops, in publication gravure (which uses solvent recovery), heatset or flexible packaging (no existing heaters of sufficient capacity).

#### Economics

The cost increases with the distance of the process to the boiler; however, in general this is a low-cost technique.

#### Driving force for implementation

No data submitted.

#### Example plants ~~No data submitted.~~

*Used in some plants responding to data collection.*

#### Reference literature

[24, ESIG, 2000] [37, Jansen, 2005] [38, TWG, 2004] [78, TWG, 2005]

### 17.10.5.2 Thermal oxidation

#### Description

Oxidation of VOCs in a simple oxidation chamber by chemical reaction with oxygen from the exhaust air.



**Achieved environmental benefits**

A removal efficiency of > 99 % (24 hours average) can be achieved; however, this depends on the inlet concentration. Commonly achieved concentration levels after treatment are in the range of 20–50 mg C/m<sup>3</sup>, and even lower levels can be achieved. Lower levels can also be achieved for halogenated solvents where required; however, lower VOC levels may require additional fuel.

Maximum levels for phenol and formaldehyde of below 20 mg/m<sup>3</sup> are reported in abrasive manufacturing.

Also used for the abatement of odour.

**Cross-media effects**

A significant amount of additional fuel is needed to achieve the required burning temperatures: the energy consumption is higher than recuperative and regenerative oxidation. Emissions of NO<sub>x</sub>, CO and CO<sub>2</sub> occur; the maximum level for each of these substances is normally below 200 mg/m<sup>3</sup>.

Noise levels may increase.

**Operational data**

Solvents in the waste gas are normally destroyed by temperatures of 680–750 °C and this ensures an almost complete combustion of the solvent load. The oxidisers normally operate with parameters adjusted for balanced minimum total emissions.

The concentration range of the inlet gas is only limited because of the maximum LEL values. The start-up time of the system is only five minutes. There are no limits to the inlet temperature.

The oxidiser should operate continuously when it is fitted with a lining system, because the lining system has to be kept warm. The amount of fuel required to keep it warm during idling times is an important consideration for systems not operating continuously.

The dust concentration should be < 3 mg/Nm<sup>3</sup>, but can be higher when incinerating organic dust particles.

The units can be integrated in the dryer or applied as a central system for several dryers.

After thermal oxidation, cleaned gas concentrations of 10 mg C/m<sup>3</sup> are reached in the automotive industry.

**Applicability**

Especially suitable for high VOC concentrations (5–16 g/Nm<sup>3</sup>) and for batch processes with all types of solvents (and their mixtures).

Small to medium flowrates < 25 000 Nm<sup>3</sup>/h can be treated. This technique is most economically applied to flowrates in the range of 5–1 000 Nm<sup>3</sup>/h and is most appropriate for batch processes, e.g. for some hours per day or week or some weeks a year. It can treat all types of solvents and solvent mixtures and no specific pre- or post-treatment is needed.

It is commonly applied in the manufacturing of abrasives especially in situations where recovered heat cannot be utilised. The technique is also applied in the automotive industry and in the coating of trucks and commercial vehicles. It was also commonly applied in the heatset printing processes; however, nowadays regenerative incineration is preferred instead.

This technique has not been applied in the winding wire industry.

**Economics**

As an investment, this technique is the lowest cost type oxidiser. However, operational costs are high because a lot of additional fuel is needed. Large capital and increased plant running costs.

### **Driving force for implementation**

Control of odour nuisance.

### **Example plants**

No data submitted.

### **Reference literature**

[14, Aminal, et al., 2002] [12, UBA Germany, 2002] [54, BMLFUW Austria, 2003] [13, DFIU and IFARE, 2002] [24, ESIG, 2000] [37, Jansen, 2005] [38, TWG, 2004] [78, TWG, 2005] [94, VITO, 2004]

### **17.10.5.3 Recuperative thermal oxidation**

#### **Description**

Similar to thermal oxidation but with a heat exchanger that preheats the incoming off-gases with the heat of the waste gases.

#### **Technical description**

The principle of destroying the solvents by burning is the same as described in Section 17.10.5.2. However, energy is saved because the waste hot air is utilised for heating the incoming cold solvent-laden air or routed back to the drying process. Although heat exchangers are applied, additional fuel might still be necessary.

#### **Achieved environmental benefits**

Close to 100 % destruction of VOCs can be achieved and commonly achieved emission levels are  $< 20 \text{ mg C/m}^3$  (24 hours average) or  $< 30 \text{ mg C/m}^3$  (hourly average). Compared to thermal oxidation, 50–70 % energy can be recuperated as total heat in the heat exchanger.

Typical achieved emission levels in the coating and printing of metal packaging are in the range of  $20\text{--}50 \text{ mg C/Nm}^3$ . In this sector, and specifically in drum manufacturing, a commonly achieved removal efficiency of 95 % with a maximum of 97 % is reported. Cleaned gas concentrations of  $10 \text{ mg C/m}^3$  are reached in car manufacturing processes. In the coil coating industry, typically achieved emissions levels are in the range  $20\text{--}50 \text{ mg C/m}^3$ .

#### **Environmental performance and operational information**

Although this technique uses less energy than a thermal oxidiser (see Section 17.10.5.2), it still consumes a considerable amount of energy if the inlet VOC concentration is below the autothermal limit, which is about  $2\text{--}3 \text{ g/m}^3$ . The burner always needs a pilot flame (consuming energy).

The concentration range of the inlet gas is only limited because of the maximum LEL values and with low VOC levels more fuel has to be added. The maximum inlet temperature is  $400 \text{ }^\circ\text{C}$ . Temperature control is needed. The VOC concentration after treatment can also be controlled continuously.

The energy released by the oxidiser comes from both gas and solvent burning. Because of the high temperature of incinerated fumes, a large part of the energy can be recovered in exchangers for use in:

- preheating of the fumes before incineration at around  $500 \text{ }^\circ\text{C}$  (to reduce the gas consumption in the incinerator);
- preheating of the air injection in the oven at a maximum of  $400 \text{ }^\circ\text{C}$ , especially in the case of 'hot air convection' ovens (to reduce or eliminate the gas consumption in the ovens);

- water heating (for process and/or sanitary use).

In the case of technologies such as ‘infrared’ or ‘induction’ drying, there is not enough data available to determine the effect on prime energy requirements. However, it is known that the same opportunities for energy recovery do not exist.

Lower levels can be achieved for halogenated solvents where required.

#### **Cross-media effects**

NO<sub>x</sub>, CO<sub>2</sub> and CO emissions occur. Noise levels might increase.

#### **Technical considerations relevant to applicability**

Small to medium flowrates of < 25 000 Nm<sup>3</sup>/h can be treated. This technique is most economically applied to flowrates in the range of 1 000–15 000 Nm<sup>3</sup>/h and it is most appropriate for continuous processes and waste gas with a solvent concentration of 6–12 g/m<sup>3</sup>. It can treat all types of solvents and solvent mixtures and no specific pre- or post-treatment is needed. This technique can operate both continuously and discontinuously because it has a relatively short start up time of less than one hour.

This technique is commonly applied in the:

- printing industry, always with additional fuel;
- coil coating industry;
- automotive industry;
- drum manufacturing industry;
- metal packaging industry; however, high VOC concentrations can cause quality problems for colour coatings, e.g. whites can be discoloured.

It is only sporadically applied in the coating of ships and not applied in the winding wire industry.

#### **Economics**

If the operating temperatures are > 700 °C, temperature-induced material fatigue can reduce the lifetime of the heat exchangers to 8–12 years. Investment costs are between EUR 150 000 and EUR 250 000 for installations with 10 000 m<sup>3</sup>/h throughput.

#### **Driving force for implementation**

Recuperative thermal oxidation is applied for energy reasons, i.e. Kyoto Paris agreement.

#### **Example plants**

No data submitted.

#### **Reference literature**

[14, Aminal, et al., 2002] [12, UBA Germany, 2002] [13, DFIU and IFARE, 2002] [24, ESIG, 2000] [27, VITO, 2003] [37, Jansen, 2005] [38, TWG, 2004] [39, SEFEL, 2004] [22, ECCA, 2004] [78, TWG, 2005]

### **17.10.5.4 Regenerative thermal oxidation –dual bed**

#### **Description:**

An oxidiser with multiple beds filled with ceramic packing. The beds are heat exchangers, alternately heated by flue-waste gases from oxidation, then the flow reversed to heat the inlet air to the oxidiser. The flow is reversed on a regular basis.

#### **Technical description**

This oxidiser is a dual bed system in which each bed is filled with ceramic packaging. One bed is used to preheat the gas stream to be treated; the other is heated by the flue-gases that arise from the oxidation. The flow is reversed on a regular basis to switch the preheat and the heat recovery beds. Some unburned VOCs are emitted during switch over.

Regenerative oxidisers that receive an inlet gas with a VOC concentration above the autothermal level are called 'flameless oxidisers'. Flameless operation can also be reached by using a direct fuel injection (only with gaseous fuel) and a sufficient concentration of oxygen in the crude gas.

**Achieved environmental benefits**

This system can achieve emission levels in the range of 10–20 mg C/Nm<sup>3</sup> (24 hour average) and removal efficiencies in the range of 95–99.5 %. The generated surplus energy may be reused and can result in significant overall energy savings.

Cleaned gas concentrations of 10 mg C/Nm<sup>3</sup> are reached in the automotive industry. In flexo and packaging gravure, levels in the range of 10–20 mg C/Nm<sup>3</sup> can be achieved. At this level the residual emission is < 0.5 % and the removal efficiency is logically > 99.5 %.

In abrasive manufacturing, the regenerative oxidiser can typically work autothermally with solvent concentrations above 2–3 g/m<sup>3</sup>. At waste air volumes of up to 66 000 Nm<sup>3</sup>/h, the installations achieve emission values of < 20 mg C/Nm<sup>3</sup> (half hourly mean value). Maximum levels for phenol and formaldehyde are below 20 mg/Nm<sup>3</sup>.

**Cross-media effects**

None if compared to conventional thermal oxidisers. Emission levels of CO, CO<sub>2</sub> and NO<sub>x</sub> are normally below 100 mg/m<sup>3</sup>. The CH<sub>4</sub> levels are normally below 50 mg/m<sup>3</sup>.

Incineration requires energy (gas), mainly during the start-up operations.

Low NO<sub>x</sub> formation can be achieved by applying low combustion temperatures in the range of 750–820 °C, or even below 750 °C. Typical achieved emission concentration is < 50 mg/m<sup>3</sup>.

Noise levels might increase.

**Operational data**

When the solvent concentration in the air to be treated is in the range of 1.5–3 g/m<sup>3</sup>, the system is autothermal and no additional fuel needs to be added. The thermal energy of the outgoing air of the waste gas treatment system is utilised for the warming up of the crude gas by alternating the heat transfer beds. With concentrations of 4–6 g/m<sup>3</sup> the excess heat can be recovered and, for example, used in production processes. To achieve these values, the concentration of the dryer airflow may require concentration as described in Section 17.10.3.1.

The system is sensitive to the presence of dust in the feed because it will plug the ceramic packaging, however, some level of combustible dust can be accepted. The temperature is controlled and after treatment, the VOC concentration can also be controlled continuously.

In the average flexo and packaging gravure printing plant, the amount of excess heat is greater than can be utilised. The main heat consumers are the dryers on the presses. Oxidising one gram of solvents can heat one m<sup>3</sup> of air by approximately 25 °C. There are approximately 3 to 4 g/m<sup>3</sup> available: enough energy to heat each m<sup>3</sup> by 75–100 °C. The required temperature rise for the drying air is, however, on average only some 30 °C. This means that, for more than half the recovered heat, other possibilities have to be found. Sometimes the surplus energy is sold to neighbouring plants. The recovered heat then needs to be transported. For this purpose, steam or thermal oil is suitable. Most dryers however operate with an open gas flame or electricity. Using the excess heat from the oxidiser for the dryers would imply replacement of all the dryers: an investment that could never be recovered with the decrease of the energy costs alone.

In the coating and printing of DWI, the excess heat may be used for certain operations, e.g. in the cleaning process and for heating the incoming air to the dryers.

In coil coating, the fumes are oxidised in twin chambers which are preheated alternately. The chambers are preheated by the fumes from the other chamber in operation. A gas burner is used for starting the installation but normally not in steady conditions. It can process a very low VOC concentration in the fumes. The energy released by the oxidation only comes from the burning solvent. Due to the energy efficiency of the regenerative oxidiser, exhaust temperatures are low, reducing the opportunity for energy recovery. Because of the process, the main part of the energy is recovered for the oxidation itself, the rest of the energy can be recovered in exchangers for preheating the air injection in the oven (at a low temperature) and for water heating (for process and/or sanitary use).

### Applicability

This technique is commonly applied to an airflow in the range of  $> 1\,500\text{--}70\,000\text{ Nm}^3/\text{h}$  for one dual bed unit. For flows  $> 70\,000\text{ Nm}^3/\text{h}$ , multibed systems are more economic. The maximum inlet temperature is  $400\text{ }^\circ\text{C}$ . The maximum VOC inlet concentration will be limited by a 25 % LEL value for safety reasons, typically  $12\text{ g/m}^3$  (for solvents such as toluene, ethylacetate or ethanol with typical LEL values of about  $40\text{ g/m}^3$  or  $50\text{ g/m}^3$ ). The safety margin is necessary to prevent explosions in the ceramic beds.

However, to achieve an emission of  $< 20\text{ mg C/Nm}^3$  (removal efficiency  $\sim 98.75\%$ ), a VOC inlet concentration of  $< 1.5\text{ g/m}^3$  is needed.

This technique can treat all types of solvents and solvent mixtures. However, with sticky substances, a regular 'burn-out' is required. With silicon hydrocarbons, regular cleaning is needed and therefore should be avoided.

This technique is most commonly applied to continuous processes. When it is applied to discontinuous processes it is normally on stand-by mode and at a certain temperature. The start-up time is one to four hours.

Regenerative oxidisers of this type are commonly applied in:

- flexo and packaging gravure printing plants;
- heatset offset printing plants;
- the manufacturing of abrasives;
- the coating and printing of metal packaging (except in drum manufacturing);
- coil coating;
- the automotive industry.

This technique is only occasionally applied in shipyards and is not applied in the winding wire industry.

### Economics

The investment for a regenerative oxidiser is higher than that of a recuperative oxidiser. The investment and operational costs of end-of-pipe abatement equipment are largely determined by the maximum airflow that needs to be treated. The investment can be estimated as: minimum EUR 200 000 for a capacity of up to  $10\,000\text{ m}^3/\text{h}$ , plus EUR 10–15 for each additional  $\text{m}^3/\text{h}$ . This includes a simple centralised collection duct, but not the cost for optimisation of the airflow (see Section 17.10.3.1). The fuel demand is low, so the electric fan mainly determines the running costs. The operating costs are some EUR 15 000 per year for treating  $10\,000\text{ m}^3/\text{h}$ .

The recovery and transportation of excess heat requires additional investment. This investment is such that it can only be recovered with lower energy costs if all the excess heat can actually be used and if no additional investments are necessary to be able to use this heat.

### Driving force for implementation

No data submitted.

### Example plants

AMCOR Flexibles in Gent, Belgium. HFP Bandstahl GmbH & Co KG in Bad Salzungen, Germany.

### Reference literature

[4, Intergraf and EGF, 1999] [18, UBA Germany, 2003] [14, Aminal, et al., 2002] [12, UBA Germany, 2002] [13, DFIU and IFARE, 2002] [24, ESIG, 2000] [27, VITO, 2003] [37, Jansen, 2005] [38, TWG, 2004] [39, SEFEL, 2004] [22, ECCA, 2004] [78, TWG, 2005]

### 17.10.5.5 Regenerative thermal oxidation – three bed or rotating air distributor

*Consider merging with Section 17.10.5.4*

#### Description

See Section 17.10.5.4 for the description of the technique, however, instead of two beds (dual bed), three beds are now installed. The third bed is called the 'purge bed'. Multibed systems (five or seven beds) are also available. Instead of multibed systems, one-vessel systems with a rotating air distributor are available. These one-vessel systems are composed of several zones (beds or pie wedges).

#### Achieved environmental benefits

A three bed system or a rotating air distributor can achieve emission levels in the range of 10–20 mg C/Nm<sup>3</sup> (24 hour average) and removal efficiencies in the range of 98–99.9 % depending on inlet concentrations and operation conditions. This can be achieved because, compared to a dual bed system, no untreated VOC emissions occur due to switching the direction of the gas flow. Compared to a conventional oxidiser, a significant energy saving is achieved. The generated surplus energy may be reused.

#### Cross-media effects

Compared to a conventional oxidiser, energy is needed to power larger fans needed to drive the exhaust air through the heat exchangers. Emissions levels of CO, CO<sub>2</sub> and NO<sub>x</sub> are normally below 100 mg/m<sup>3</sup>, and of CH<sub>4</sub> normally below 50 mg/m<sup>3</sup>. Noise levels might increase.

#### Operational data

This technique is commonly applied for airflows in the range of > 1 500–120 000 Nm<sup>3</sup>/h for one three bed unit. For flows >70000 Nm<sup>3</sup>/h, multibed systems are more economic. The maximum inlet temperature is 400 °C. The maximum VOC inlet concentration will be limited by the maximum LEL value, theoretically 12 g/m<sup>3</sup>.

The system works autothermally with VOC concentrations in the range of 1.5–3 g/m<sup>3</sup>, but the system is also applicable with concentrations of > 3 g/m<sup>3</sup>. With concentrations above the autothermal point, excess heat can be recovered and reused.

This technique is most commonly applied to continuous processes. When it is applied to discontinuous processes, it is normally on stand-by mode and at a certain temperature. The start-up time is one to four hours.

It can treat all types of solvents and solvent mixtures; however, with sticky substances a regular 'burn-out' is required. With silicon hydrocarbons, a regular cleaning is needed and, therefore, should be avoided.

The system is sensitive to the presence of dust in the feed; however, some level of combustible dust can be accepted.

**Applicability**

Regenerative oxidisers of this type are commonly applied in:

- flexo and packaging gravure printing plants;
- heatset offset printing plants;
- the manufacturing of abrasives;
- the coating and printing of metal packaging;
- coil coating;
- the automotive industry.

The technique is only occasionally applied in shipyards and is not applied in the winding wire industry.

**Economics**

Compared to the dual bed system, the additional investment is about 25 %.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[24, ESIG, 2000] [27, VITO, 2003] [37, Jansen, 2005] [38, TWG, 2004] [78, TWG, 2005]

**17.10.5.6 Catalytic oxidation****Description**

Oxidation of VOCs assisted by a catalyst to reduce the oxidation temperature and reduce the fuel consumption. Exhaust heat can be recovered with recuperative or regenerative types of heat exchangers. Higher oxidation temperatures (500–750 °C) are used for the treatment of off-gas from the manufacturing of winding wire.

~~Oxidation of VOCs is made in the presence of a catalyst (usually platinum). Because of the catalyser, the required temperatures in the oxidation process can be reduced to 250–400 °C. However, in winding wire manufacturing, the temperature in the oxidation process is in the range of 500–750 °C. Exhaust heat can be recovered and recuperative or regenerative types of heat exchangers can be applied.~~

**Achieved environmental benefits**

Removal efficiencies of 95–99 % are achieved. The typically achieved concentration range is 10–50 mg C/Nm<sup>3</sup>. Compared to thermal oxidation (see Section 17.10.5.2), less additional fuel is needed. Applying a catalyser in combination with recuperation of the exhaust heat requires less energy than recuperative oxidation without a catalyser, see Section 17.10.5.3.

Typically achieved emission levels in winding wire production are 5 g VOC/kg product for wires with an average diameter of above 0.10 mm, and 10 g VOC/kg product for wires with an average diameter of below 0.10 mm. Legal emission limit values of 20 mg C/m<sup>3</sup> are reported to be met.

In the printing industry, the above-mentioned removal efficiencies can be achieved under the following condition: a flow of 1 000–30 000 Nm<sup>3</sup>/h or higher and a VOC concentration of > 1–2 g/Nm<sup>3</sup>. Typical levels in heatset printing (although rarely used currently) and in the coil coating industry are in the range 20–50 mg C/Nm<sup>3</sup>.

**Cross-media effects**

Catalysts must be replaced/recharged periodically. Additional fuel is needed; however, less compared to thermal oxidation. Noise levels might increase.

Typically achieved emission levels of CO and NO<sub>x</sub> are < 50 mg/m<sup>3</sup>.

In the winding wire industry, reported emission levels for NO<sub>x</sub> are about 10 g/kg product for wires with a diameter of an average above 0.10 mm, and 12.5 g/kg product for wires with a diameter of an average below 0.10 mm (see Section 17.10.8). However, this is dependent on the quantity of N-containing solvent in use.

### Operational data

VOC concentrations of up to 5 g/Nm<sup>3</sup> can be treated. This technique can be applied for airflows in the range of 10–30 000 Nm<sup>3</sup>/h. However, it is most suitable for discontinuous airflows of up to 10 000 Nm<sup>3</sup>/h.

At inlet temperatures above 400 °C, no preheating is required to reach the start temperature of the catalyst. Normally, oil is not used as a fuel, due to the sulphur content and related toxicity to the catalyst.

This technique can be operated continuously or discontinuously, however, when continuously operated, the lifetime of the catalyst is limited to about 15 000–25 000 hours.

All types of solvents and solvent mixtures can be treated. However, the presence of contaminants which could poison the catalyst must be checked. If the inlet concentration is too high, it may lead to overheating and damage to the catalyst. This technique is also very sensitive to the presence of dust or droplets in the feed and therefore pretreatment of the airflow is required. It is also sensitive to changes in the inlet concentration. Halogenated or silicon hydrocarbons and silicons may also cause problems.

### Applicability

This technique, including the recuperation of the exhaust heat, is commonly applied in the winding wire industry. It is rarely used in the coil coating industry. The automotive industry has tested this technique, but due to problems with blinding, it has not been generally applied.

Catalytic oxidation is used in a limited number of cases in the printing industry, and only in heatset printing processes. Nowadays, in these situations, regenerative oxidation is preferred to catalytic oxidation.

### Economics

The usual cost issue of this technique is the catalyst that needs to be exchanged at the end of its lifetime and this can only be checked by regular measurements. However, in general the costs are comparable to those for a regenerative oxidiser.

The prices below are representative for the Flemish wood industry and based on realistic theoretical working parameters. Equipment suppliers that provided the information stressed that it is impossible to extrapolate the costs of the examples on the basis of flows and VOC loads, so the numbers are purely indicative and valid at the time estimations were made (November 2004).

Price quoted by supplier A:

- 1) Flow: 15 000 Nm<sup>3</sup>/h
  - VOC inlet concentration: 1500 mg/Nm<sup>3</sup>, VOC emission: <20 mg/Nm<sup>3</sup>
  - Price: EUR 325 000.
- 2) Flow: 59 000 Nm<sup>3</sup>/h
  - VOC inlet concentration: 300 mg/Nm<sup>3</sup>, VOC emission: <50 mg/Nm<sup>3</sup>
  - Price: EUR 628 000 to EUR 770 000.

Price quoted by supplier B:



- 1) Maximum flow: 15 000 Nm<sup>3</sup>/h
- VOC inlet concentration: 1500 mg/Nm<sup>3</sup>, VOC emission: <90 mg/Nm<sup>3</sup>
  - Price: EUR 300 000.

### Driving force for implementation

No data submitted.

### Example plants

No data submitted.

### Reference literature

[14, Aminal, et al., 2002] [12, UBA Germany, 2002] [22, ECCA, 2004] [24, ESIG, 2000] [27, VITO, 2003] [28, EWWG, 2004] [37, Jansen, 2005] [38, TWG, 2004] [78, TWG, 2005] [95, CEI-BOIS, 2006]

### UV-oxidation

*ESVOC propose deletion TWG please confirm, see Applicability, below*

**Description:** Solvent laden air is routed through a series of UV lamps. VOC molecules are fragmented by the short wavelength energy and ozone is formed from the oxygen. The ozone reacts with the fragmented VOC molecules which lead it to partly oxidise. The subsequent unit contains a catalytic agent (mainly TiO<sub>2</sub>), the oxidation of the ozone and VOC molecules continues and the excess ozone is destroyed.

**Achieved environmental benefits:** For a waste gas with a VOC concentration of 0.5 g/Nm<sup>3</sup>, the removal efficiency is about 95 %. VOC concentrations in the treated waste gas of 25–50 mg/Nm<sup>3</sup> are achievable.

**Cross-media effects:** Energy consumption from the lamps and exhaust ventilator together are 50 kWh per 1000 m<sup>3</sup> waste gas treated. The lamps emit O<sub>3</sub> (which is destroyed), and contain mercury which has to be disposed of with suitable precautions. Noise levels might increase.

**Operational data:** The temperature of the waste gas should not exceed 60 °C and the humidity should be less than 85 %.

The technique was originally developed to achieve odour reduction and for the destruction of toxic substances. However, increasingly the technique is used for the complete destruction of VOCs, especially in waste gases containing low concentrations (on average <0.5 g/Nm<sup>3</sup> and occasionally peaks of <1.0 g/Nm<sup>3</sup>).

**Applicability:** Applicable to the wood and furniture painting industry when applying solvent based paints. However, the technique is currently not applied in this industry.

Not applied in the vehicle paintshops.

The technique is currently applied in the metallurgical industry and in electronics to treat VOC emissions from spray booths where solvent-based paints are applied.

**Economics:** In an installation that can treat several 10000 m<sup>3</sup>/h, investment costs are about EUR 5000–7000 per 1000 m<sup>3</sup>/h waste gas. After 8000 hours the UV lamps need to be replaced; costs are about EUR 0.06–0.2 per 1000 m<sup>3</sup>/h waste gas. Energy costs are about EUR 4 per 1000 m<sup>3</sup>/h waste gas. The operational costs (including lamps, energy and catalyser) are in the range EUR 3–25 per kilo VOC removed.

In the specific situations where this technique is used, UV oxidation has been reported to be cheaper compared to adsorption to activated carbon or any type of thermal oxidation. However, no data exist to confirm this applies to IPPC size installations.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [14, Aminal, et al., 2002] [13, DFIU and IFARE, 2002] [24, ESIG, 2000] [27, VITO, 2003] [38, TWG, 2004] [78, TWG, 2005].

## 17.10.6 Techniques for the capture of solvents in waste gases

### 17.10.6.1 Condensation

#### Description

Off-gas with a high VOC concentration is cooled to the point of condensing the VOCs. The volatility of the VOCs determines the type of cooling required

#### Technical description

Annex 21.9 provides a summary of waste gas treatment techniques (oxidation, adsorption, condensation and biological treatment) and their applicability. A comparison of the removal efficiencies of the most widely used techniques is given for different types of solvents at different inlet concentrations [97, TWG, 2006].

#### Achieved environmental benefits

Reduction of VOC emissions. Collected solvents may be reused or recycled.

#### Environmental performance and operational information

The VOC rich gas is cooled to the point where a significant portion of the vapours condense. Heavy, low volatile solvents can be recovered at room temperature; highly volatile solvents need to be cooled well below 0° C to recover about 95 % or more. Cooling this low has the important disadvantages of high energy costs and water freezing the cooling elements. Cooling just above 0° C avoids ice, but condenses water, and this may end up in the recovered solvent, necessitating expensive dehydration.

Typically in condensation processes, the solvents can be reused. ~~The different condensation techniques are discussed in the following sections.~~

#### Cross-media effects

Energy consumption.

#### Technical considerations relevant to applicability

See Annex 21.9. May not be applicable to low-VOC concentration off-gas streams.

#### Economics

No information provided.

#### Driving forces for implementation

Workplace health and safety.

#### Example plants

[155, TWG, 2016]

#### Reference literature

No information provided.

**Direct cooling***ESVOC propose deletion*

**Description:** The VOC rich gas is cooled by direct contact with a cold stream in a scrubber. The technique cool sorption combines the effects of absorption and direct contact condensation.

**Achieved environmental benefits:** VOCs can be recovered and possibly re-used. The removal efficiency is higher on concentrated streams.

**Cross-media effects:** Energy is required for cooling.

**Operational data:** This technique applied alone may not meet some of the statutory requirements for concentration levels in waste gas.

**Applicability:** Cool sorption is often used as a first clean up step for waste gases.

This technique is not applied in printing processes, the winding wire industry or in vehicle paintshops.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [24, ESIG, 2000] [38, TWG, 2004] [78, TWG, 2005]

**Indirect cooling***ESVOC propose deletion*

**Description:** The VOC rich gas is cooled in a heat exchanger using cooling water or another medium at temperatures above 0 °C.

**Achieved environmental benefits:** VOCs can be recovered and possibly re-used. The removal efficiency is higher on concentrated streams; however in general, it is a low efficiency process.

**Cross-media effects:** Energy is required for cooling. Waste water will arise which may need to be treated before discharge.

**Operational data:** This process may be useful on concentrated streams with low volatile solvents; however, it is usually combined with another treatment.

**Applicability:** Condensation by applying temperatures above 0 °C is only applicable to low volatile solvents. This technique is applied in heatset offset printing processes, where inks based on low volatile solvents are applied.

A serious drawback of this technique when used in heatset offset printing processes is that IPA is not removed from the waste gas. Plants using >25 tonnes solvents per year are therefore facing difficulties in meeting the emission limit of 20 mg C/Nm<sup>3</sup> (set in the Solvent Emissions Directive). The offensive smell of the heatset waste gases is not completely eliminated. This technique is not applied in the winding wire industry or in vehicle paintshops.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [24, ESIG, 2000] [38, TWG, 2004] [78, TWG, 2005]

## Refrigeration

### *ESVOC propose deletion*

**Description:** The VOC rich gas is cooled in a heat exchanger using a refrigerated medium at temperatures below 0 °C. Usually a two condenser system is used alternately in condensation and in defrosting mode.

**Achieved environmental benefits:** VOCs can be recovered and possibly re-used. The removal efficiency is higher on concentrated streams.

**Cross-media effects:** Energy is required for cooling. Noise levels might increase.

**Operational data:** Humidity in the waste gas will cause icing to occur, requiring de-icing at regular intervals. Usually a condensation step at temperatures above 0 °C is used upstream to reduce the water content.

**Applicability:** Gases with high water vapour contents are less suitable because of the increased icing effect. This process may be useful on streams with high volatile solvents. This technique is applied in adhesive tape manufacturing, in new and existing plants.

This technique works best on waste gases with a very high solvent concentration of several 100 g/m<sup>3</sup>. For these types of waste gases, closed drying systems using inert gas (N<sub>2</sub>) are required because of the LEL value, which is about 20 g/m<sup>3</sup> at 40 °C. However, closed drying systems using inert gas can only be successfully used where the drier does not need be opened too often. After testing, it showed that it was for this reason that the technique is not applicable in flexible packaging printing, where the job changes several times per day and the driers need to be opened too frequently.

This technique is not applied in other printing processes or in vehicle paintshops.

**Economics:** The capital costs of an adhesive tape manufacturing example plant with a capacity of 400 kg/hr for the condensation installation were about EUR 0.88 million in 1992. Operating costs for adsorption and condensation together were about EUR 0.51 million/yr. Variable costs were about EUR 1.12 million/yr and fixed costs about EUR 1.38 million/yr.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [24, ESIG, 2000] [38, TWG, 2004] [78, TWG, 2005]

### 17.10.6.2 Cryogenic solvent recovery treatment

#### Description

Cooling (usually by using liquid nitrogen) the waste gas to temperatures below the dew point so that the solvent vapour condenses on a cooling surface and can be removed in liquid form. The lower the temperature the smaller the remaining load in the gas flow. The highly volatile solvent rich gas is exposed to very low temperatures.

#### Technical description

Cryo-condensation is a very economical method and ideally suited for treatment of process gases with high or medium solvent concentration (usually 50 g/m<sup>3</sup> to 1 000 g/m<sup>3</sup>) and low flow

rates (10 Nm<sup>3</sup>/h to 2 000 Nm<sup>3</sup>/h). The liquid nitrogen required for the process is not consumed in the system, only its cooling effect is utilised and after evaporation in the condenser the gas is often reused by the customer (e.g. for inerting).

#### **Achieved environmental benefits**

Theoretically, very high removal efficiencies can be achieved if the temperatures are low enough. However, practically, the temperatures will not be lower than -95 °C and at this temperature, low concentration levels cannot be achieved.

Removal efficiencies of 99 % or more can be achieved resulting in concentrations in the treated gas of 1–5 g/Nm<sup>3</sup>. This can, for example, be achieved by treating a gas flow of 0–1 000 Nm<sup>3</sup>/h with an incoming VOC concentration in the range of 200–1 000 g/Nm<sup>3</sup>. The recovered VOCs can be reused.

#### **Cross-media effects**

Energy is required for cooling the liquid nitrogen. Noise levels might increase.

#### **Operational data**

The vaporised nitrogen can be used in the plant for blanketing purposes. If post-treatment is necessary, often an adsorption technique is applied.

#### **Applicability**

This technique is mainly applied to relatively small gas flows (up to 50 m<sup>3</sup>/h) and on batch emissions. Continuous systems with a capacity of 250 m<sup>3</sup>/h or more are less frequently applied.

This technique is applied for the treatment of waste gases from paint application and dryers. However, it is not applied in wood and furniture painting, the winding wire industry, the coil coating industry, printing processes or vehicle paint shops.

Gases with a high water vapour content are less suitable because this will lead to the formation of ice.

#### **Economics**

Investment costs are about EUR 500 000 per 1 000 Nm<sup>3</sup>/h waste gas, excluding the storage facilities for nitrogen.

Energy costs are negligible. Costs for nitrogen use are about EUR 0.12 per kilo nitrogen assuming a capacity of 1 000 Nm<sup>3</sup>/h waste gas treated.

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

# 024 Sidac, S.p.A., Forlì, IT (flexographic installation with a flow rate of 45000 m<sup>3</sup>/h) ~~No data submitted.~~

#### **Reference literature**

[24, ESIG, 2000] [27, VITO, 2003] [38, TWG, 2004] [78, TWG, 2005] [155, TWG, 2016]  
<https://www.messergroup.com/cryogenic-solvent-recovery-the-technology>

#### **Condensation above freezing point**

##### ***ESVOC propose deletion***

~~**Description:** Condensation above freezing point requires very high solvent concentrations (preferably several 100 g/m<sup>3</sup>). Only a part of the solvent is condensed. The air with the remainder of the solvent cannot be emitted, but is sent back to the drying process. This in turn~~

requires (for safety reasons) a closed loop of inert gas, and not ordinary air in which the solvent concentration is always at a very high level (for example, inlet 100 g/m<sup>3</sup>, outlet 200 g/m<sup>3</sup>).

**Achieved environmental benefits:** Solvent recovery and low emissions from a sealed system.

**Cross-media effects:** No data submitted.

**Operational data:** No data submitted.

**Applicability:** No data submitted.

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [78, TWG, 2005]

[Adsorption]

Annex 21.9 provides a summary of waste gas treatment techniques (oxidation, adsorption, condensation and biological treatment) and their applicability. A comparison of the removal efficiencies of the most widely used techniques is given for different types of solvents at different inlet concentrations [97, TWG, 2006].

### 17.10.6.3 Adsorption using activated carbon or zeolites

#### Description

VOCs are adsorbed on the surface of activated carbon or zeolites. It is also commonly applied as a 'concentrating up' pretreatment to increase the oxidation efficiency. Continuous monitoring of the outlet concentration of VOCs is carried out to check the adsorption efficiency. Both the solvents and the adsorption media (activated carbon or other adsorbent) are recovered

#### Technical description

The technique is used to adsorb VOCs on the surface of activated carbon or zeolite. It is also commonly applied as a 'concentrating up' pretreatment to achieve a more concentrated waste stream that can be incinerated more economically.

During operation of the activated carbon (or zeolite) bed in the adsorption column or rotating adsorption wheel, more and more solvent will build up in the bed. At a certain time, the efficiency of the adsorption bed will decrease and the outlet concentration will start to increase. At this point, the adsorption needs to be reactivated and the solvents may be recovered or destroyed. Desorption is often performed by sweeping with a hot gas stream (nitrogen, air, or steam), but can also be done by vacuum (pressure swing adsorption). In cases where the waste gas flow is small (e.g. to solvent washing machines) the adsorbent may be regenerated off-site (see Section 17.12.7.2).

After a longer period, the adsorbent cannot be fully reactivated by removing the solvent, and requires a different type of reactivation (usually by heat treatment). This can be done on-site or off-site (see Section 17.12.7.1). If activated carbon or other adsorbents are used which cannot be regenerated, the activated carbon is disposed of (see Section 17.12.7.3).

Continuous monitoring of the outlet concentration is needed to check if the adsorption efficiency of the activated carbon is still sufficient (see Section).

Beds can be used in parallel and/or in sequence. In the case of a 2-bed system, one is in adsorption mode and the other in desorption mode, or in the case of a 3-bed system, two are used in adsorption mode and one in desorption mode.

#### **Achieved environmental benefits**

Adsorbers can achieve a removal efficiency of > 99 %; however, this is related to the inlet concentration. For example, with an inlet concentration of > 7 g/m<sup>3</sup>, removal efficiencies of > 99 % can be achieved. VOC concentrations of < 50 mg C/m<sup>3</sup> (24 hour average) can be achieved with levels of < 20 mg C/m<sup>3</sup> being possible.

In the automotive industry, adsorption materials such as carbon fibre paper, zeolites and activated carbon are used. A transmission of the solvent load into an external hot-air stream in the ratio of 1:6 to 1:30 (depending upon raw gas concentration) is achieved.

In adhesive tape manufacturing, emission concentrations of 70–90 mg/m<sup>3</sup> are achieved in the cleaned gas. Lower concentrations can be achieved; however, only by a reduction in adsorption periods and are, hence, correlated to an increased steam production. The recovery process (see Section 17.12.7.1) normally uses 2–3 kg steam per kg recovered solvent to achieve emission concentrations of 70–90 mg/m<sup>3</sup>.

Desorption and reactivation reduce carbon consumption. The condensed steam can be reused for cleaning the adsorber and as boiler water. The drying air can also be recycled after the desorption process.

#### **Cross-media effects**

In processes for the recovery of the solvents, steam is used and thus water and energy are used. The condensed steam contains traces of solvents. Noise levels might increase. Waste water arises from recovering the activated carbon.

Finding an optimum adsorption/desorption cycle means finding a balance between an acceptable emission concentration and the resources needed (i.e. energy, absorbent which needs replacing periodically, water), and the waste water generated for cleaning the carbon bed when using steam.

Requires a careful balance of the gas flows as unpredictable exothermic reactions are possible (see Operational data, below).

#### **Operational data**

Adsorption is not applicable to reactive compounds such as aldehydes and ketones because they may polymerise on the activated carbon, leading to overheating. The polymers will not desorb, therefore, MEK and similar products are not suitable. However, this problem can be overcome if proper safety measures are implemented, such as always desorbing the system before weekends and holidays, and installing automatic sprinkler systems.

It is also not applicable to gases with a relative humidity of > 60 %, because water vapours will also adsorb on the activated carbon, reducing the adsorption capacity available for VOCs. Hydrophobic zeolites are available which do not have this problem. The system is sensitive to the presence of dust in the feed, because it will plug the adsorbent bed.

Adsorption wheels can be applied as a pretreatment to thermal oxidation. This leads to a reduction in the energy requirements of thermal oxidation (see Section 17.10.5.2). It also reduces the physical size of a thermal oxidiser when used together.

#### **Applicability**

This technique can be applied to waste gases with solvent concentrations of > 0.8 g/m<sup>3</sup>. LEL limits do not play a role. The system can be applied to single solvents and mixtures. When single solvents that are not miscible with water are adsorbed, regeneration can be done with

steam. When mixtures of solvents are adsorbed, regeneration has to be done with heated nitrogen and temperatures in the range of 150–300 °C.

Airflows in the range of 1 000 m<sup>3</sup>/h to 1 million m<sup>3</sup>/h can be treated. For the upper end of the range, a 14-bed unit would be needed. The capacity of one bed depends only on the transportation of the system. The system can work continuously and discontinuously, and technically has a lifetime of more than 30 years. However, during this time it is likely to need to be adapted or renewed for environmental requirements, changes to process equipment and/or solvent systems, etc. making the economic life shorter.

This technique is applied in all publication gravure printing plants and is commonly applied in the automotive industry, the coating of trucks and commercial vehicles and in adhesive tape manufacturing as the concentration step prior to incineration. To a lesser extent, it is applied in processes using mixtures of solvents, such as in flexo and packaging gravure, although in Italy this technique has already been used for years to recover ethyl acetate.

Adsorption is especially suitable when concentrations of up to 4 g/m<sup>3</sup> have to be removed from the waste gas. However, it is also applied to concentrations of 10 g/m<sup>3</sup> or 12 g/m<sup>3</sup>. In general, it is applicable for gases containing medium to low concentrations of VOCs. Only small molecules can be adsorbed and desorbed. In the automotive industry, there are some applications used for the cleaning of air from spray booths; typical inlet concentrations are between 300–1 200 mg/m<sup>3</sup>.

Some low volatility solvents may adhere to the activated carbon permanently and quickly reduce the adsorption capacity with early replacement of the activated carbon as a result.

Adsorption and recovery of toluene used in the publication gravure processes is common practice. Toluene adsorbs well to activated carbon and is easily retrieved by heating the carbon with steam. The steam and solvent vapours are condensed to remove the toluene. The condensed steam can have a toluene concentration of between 380–540 mg/l and a stream of air bubbles is used to strip the toluene from the water. With stripping, this stream can have a concentration of toluene in the range 1–10 mg/l. After being treated, the waste water is discharged or reused as, for example, cooling water or steam. The toluene is in part reused and in part sold back to the ink manufacturers. This recovery process normally uses some 3–6 kg of steam per kg of recovered toluene. For a standard four press plant, about 7 000 tonnes of toluene per year are recovered by using 20 000–30 000 tonnes of water.

In processes where solvent mixtures are applied, such as in the flexo and packaging gravure, adsorption and recovery are both more difficult. Ethanol and ethyl acetate do not adsorb to carbon as well as toluene and subsequently larger carbon beds are required. Steam cannot be utilised for the recovery, because these solvents dissolve in water. Therefore, usually a hot inert gas, such as N<sub>2</sub> is used. To separate the recovered solvent mixture, a distillation process is necessary.

In adhesive tape manufacturing, the recovery process normally uses 2–3 kg steam per kg recovered solvent to achieve emission concentrations of 70–90 mg/m<sup>3</sup>.

In the Netherlands and the Flanders region of Belgium, this technique is not applied in flexo and packaging gravure.

### **Economics**

In general, this technique is twice as expensive as oxidation. The investment in solvent recovery will be EUR 0.5–1 million more than the investment in an oxidiser. However, there is a payback from the recovered solvent. The investment in solvent recovery will be EUR 0.5–1 million more than the investment in an oxidiser. Zeolite as the adsorption medium is about 10 times more expensive than activated carbon, and is commonly applied for concentrating-up purposes.



It should be noted that adsorption units can be designed for achieving very low emission values by increasing the total surface of the activated carbon or by applying shorter adsorption cycles. However, it has to be considered that both options result in higher investment and operational costs and a higher energy consumption.

The capital costs of adsorption equipment in an adhesive tape manufacturing example plant with a capacity of 800 kg/h were about EUR 2.7 million in 1992. Operating costs for adsorption and condensation together were about EUR 0.51 million/yr. Variable costs were about EUR 1.12 million/yr and fixed costs about EUR 1.38 million/yr.

In the case of flexo and packaging gravure, investment and running costs for adsorption and subsequent solvent recovery are higher than those of any thermal treatment. The running costs are between EUR 0.15 and 0.25 per recovered kg of solvent. The costs for recovery are EUR 0.10/kg solvent and savings are EUR 0.60–0.70/kg solvent recovered, if the solvent is reused on site. Where the solvent consumption is less than 500 tonnes per year, it is very unlikely that solvent recovery will be an economically attractive alternative to oxidation.

In packaging gravure processes, if ethyl acetate generally makes up over 90 % of the total solvent used, the reusable amount may be such that the plant becomes almost self-sufficient and no longer needs to buy ethyl acetate for dilution purposes.

The prices below for activated carbon adsorption are representative for the Flemish wood industry and based on realistic theoretical working parameters. Equipment suppliers that provided the information stressed that it is impossible to extrapolate the costs of the examples on the basis of flows and VOC loads., so the numbers are purely indicative and valid at the time estimations were made (November 2004).

- installation rental: EUR 6 052–8 544/year;
- purchase of the installation: EUR 22 355–23 740/unit;
- price quoted for: 10 000 Nm<sup>3</sup>/h and 500 mg VOC/Nm<sup>3</sup> (220 working days/year, 8 hours/day, VOC emission standard 90 mg/m<sup>3</sup> and time load of 50%):
  - activated carbon: EUR 8 316 for 5 400 kg (lasting 82 working days) = EUR 22 311/year;
- price quoted for: 1 000 Nm<sup>3</sup>/h and 500 mg VOC/Nm<sup>3</sup> (other working conditions equal):
  - activated carbon EUR 8 316 for 5 400 kg (lasting 823 working days) = EUR 2 230/year.

#### **Driving force for implementation**

May be more economic than oxidation techniques.

#### **Example plants**

Ford, Daimler Chrysler, VW, Renault, Audi, Toyota plants across Europe. RSDB in Etten-Leur, the Netherlands; and the Italian packaging gravure industry which recovers and reuses ethyl acetate.

#### **Reference literature**

[4, Intergraf and EGF, 1999] [14, Aminal, et al., 2002] [14, DFIU and IFARE, 2002] [24, ESIG, 2000] [26, CITEPA, 2003] [37, Jansen, 2005] [38, TWG, 2004] [78, TWG, 2005] [27, VITO, 2003] [96, Presti, 2005] [96, Presti, 2005] [95, CEI-BOIS, 2006].

#### **Continuous monitoring of the adsorber performance**

*To be merged with the technique, above*

#### **Description**

Monitoring equipment is available to continuously control the performance of the adsorber, e.g. continuously comparing the level of contaminants in the raw gas and those in the treated waste gas.

### **Achieved environmental benefits**

Reduction of untreated emissions because a poorly functioning adsorber can rapidly be detected and corrective action can be taken.

### **Cross-media effects**

### **Operational data**

In case the system consists of two or more parallel adsorption units, the monitoring can be used to switch from one to the next. It is reported that, in the automotive industry where concentration variations are small, measurements once a week or even less frequently are normally carried out by portable equipment.

It is common practice in publication printing plants. In publication gravure, control of the carbon bed recovery cycle is carried out by concentration measurements and at fixed time intervals. This helps to decide when the coal-bed in the toluene adsorption systems has to be cleaned. Since the solvent content of the drying air is variable, these two methods of controlling the carbon bed recovery cycle may switch the adsorbers either too soon or too late. Too soon leads to excessive energy consumption, too late increases emissions disproportionately.

### **Applicability**

This technique is applicable to new and existing adsorbers, independent of the type of industry. Continuous monitoring is only required if concentrations are large or in the case where parallel adsorption equipment is used. It is not needed where the absorber is an integral part of an abatement system and there are no releases to the air. It is also applicable to solvent recovery (see Sections 17.12.7.1 and 17.12.7.2).

### **Economics**

It is reported that the cost of the installation of four continuous measuring VOC devices including the software and access platforms was EUR 2 million in 2004.

### **Driving force for implementation**

No data submitted.

### **Example plants**

VW Hannover, Germany (cabin air treatment from solvent-borne filler application).

### **Reference literature**

[18, UBA Germany, 2003] [78, TWG, 2005]

#### **17.10.6.4 Wet scrubbing**

*ESVOC propose deletion: used in textile coating*

#### **Description**

Wet scrubbing is a mass transfer between a soluble gas or dust and a solvent – often water – in contact with each other.

~~Absorption (or wet scrubbing) to water is a mass transfer between a soluble gas and a solvent – often water – in contact with each other.~~

#### **Technical description**

Wet scrubbing is a mass transfer between a soluble gas or dust and a solvent – often water – in contact with each other. Physical scrubbing is preferred for chemical recovery, whereas chemical scrubbing is restricted to removing and abating gaseous compounds. Physico-chemical scrubbing takes an intermediate position. The component is dissolved in the absorbing liquid and involved in a reversible chemical reaction, which enables the recovery of the gaseous component

A full description of the wet scrubbing process and the types of wet scrubbing equipment available is given in the CWW BREF. The abatement efficiency of wet scrubbers is dependent on the residence time of the gas in the absorption section, the type of scrubber used, e.g. the column internals (random packing, structured packing, etc.), the scrubbing liquid used and the liquid to gas ratio. If the scrubbing liquid is recirculated, the refreshment rate of the liquid and the addition rate of any chemicals can also be important.

Absorbed solvents may be recovered for reuse (e.g. DMF in PU coating of textiles).

#### **Achieved environmental benefits**

- Recovery of VOC for reuse.
- Reduced emissions to air.

#### **Achieved environmental benefits**

Removal of gaseous pollutants, such as NO<sub>x</sub>, hydrogen halides, SO<sub>2</sub>, ammonia, hydrogen sulphide or VOCs (if water soluble, such as IPA, ethanol, DMF, etc.).

#### **Cross-media effects**

No data submitted.

#### **Operational data**

No data submitted.

#### **Applicability:**

Generally applicable. Water-based scrubbing is applicable to polar VOCs. Used in textile coating to recover water-soluble solvents such as DMF. Not applied in vehicle paint shops or printing.

#### **Economics**

No data submitted.

#### **Driving force for implementation:**

No data submitted.

#### **Example plants:**

Sioen, Ardoorie, BE, Seyntex, Tielt, BE.

#### **Reference literature**

[67, EIPPCB, 2003] [78, TWG, 2005] [178, COM 2017] [179, COM 2017]

#### **Absorption to oil and recovery**

See Section 17.10.6.4

~~**Description:** Solvents in the waste gas can be recovered by absorption into organic oils followed by distillation.~~

~~**Achieved environmental benefits:** The recovered solvent can be reused. In the cleaned gas, concentrations of <30 mg/m<sup>3</sup> can be achieved.~~

~~**Cross-media effects:** Depending on the details of the applied technique, about 0.1–0.5 m<sup>3</sup> waste water, from humidity in the air, can arise per tonne of solvent recovered. However, usually no waste water arises at all, because it is separated in the distillation equipment and reused for cleaning or converted into steam for stripping. Noise levels might increase.~~

~~**Operational data:** This technique is only used for pure solvents due to economic reasons. The technique is suitable for waste gas loads with a minimum of 2 g/m<sup>3</sup>.~~

**Applicability:** Applicable in new and existing plants. This technique is reported in one flexible packaging plant for coating and lamination; however, it is not commonly used because of cost.

It is not applied in the winding wire industry, because the solvents cannot be reused in the process. It is not applied in other printing processes, coil coating processes, the metal packaging industry or in the automotive industry, because these industries generally use mixtures of solvents.

**Economics:** The technique is more expensive than absorption using activated carbon.

**Driving force for implementation:** No data submitted.

**Example plants:** The flexible packaging company Bischof und Klein in Germany, where ethyl acetate is recovered by absorption in phthalic acid ester.

**Reference literature**

[14, DFIU and IFARE, 2002] [38, TWG, 2004] [78, TWG, 2005]

### 17.10.6.5 Absorption in liquid

[211, DE, 2016]

**Description**

Recovery of solvents by absorption to a solvent. Usually referred to as wet scrubbing when water is the solvent, e.g. as in the case of polar solvents such as DMF, IPA, and ethanol.

**Description**

Absorptive waste gas abatement systems are used to concentrate VOC in waste gases for recovery or for combustion. The system consists of:

- filter unit (absorption system);
- desorber (desorption system); and
- condensation (solvent recovery); or
- thermal oxidation (energetic use).

The decision for one of the two options depends on local conditions and is determined by economics. It mainly depends on the need for heat vs. the possibilities to reuse recovered solvents.

Volatile organic compounds originating from the vehicle coating process are collected in the absorption system, which reduces VOC emissions to air. Subsequently, the sorption fluid laden with organic solvents is directed to the desorption unit where solvents are removed from sorption fluid. This is achieved with hot air, which passes through the heated absorbent in a counter current flow.

The hot air laden with solvents is conducted to the condensation plant or to the thermal oxidation.

Figure 17.17 illustrates the absorption of volatile organic compounds in the sorption fluid, the desorption by hot air in the desorption unit and the subsequent options for using the concentrated solvents.

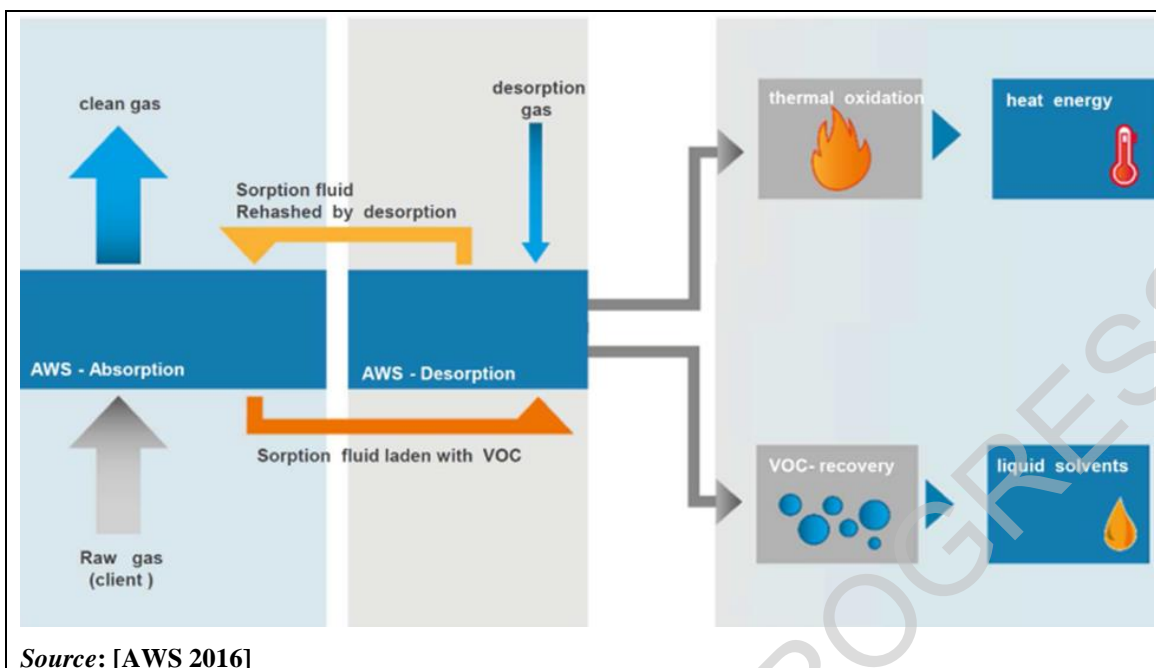


Figure 17.17: Scheme of the absorption waste gas abatement system

The absorption process takes place in a module that produces a film curtain by means of porous so-called Keder tubes. The curtain offers a large surface for the cross-counter-current of the waste gas.

The modules are characterised by a low pressure loss on the exhaust side. Several modules can be combined in series, depending on the concentration of the waste gas and on the composition of the substances to be absorbed. Absorbent and waste gas are conducted in a cross-counter-current.

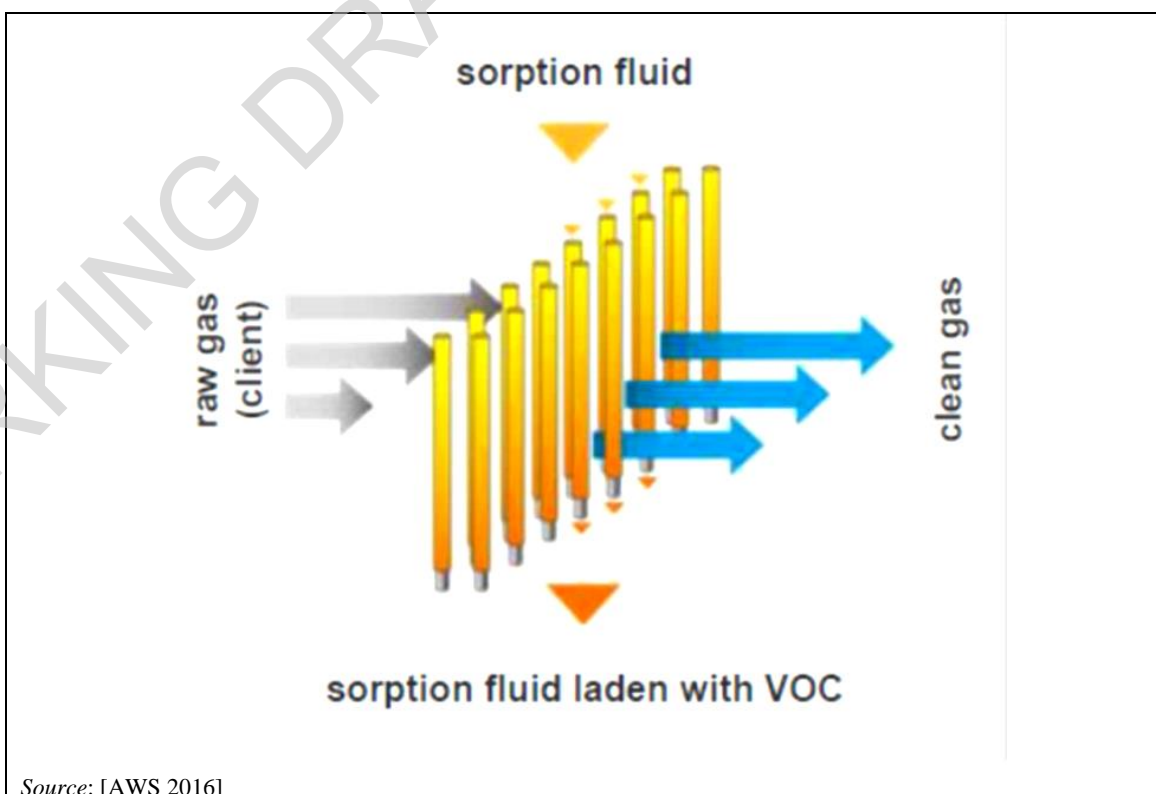
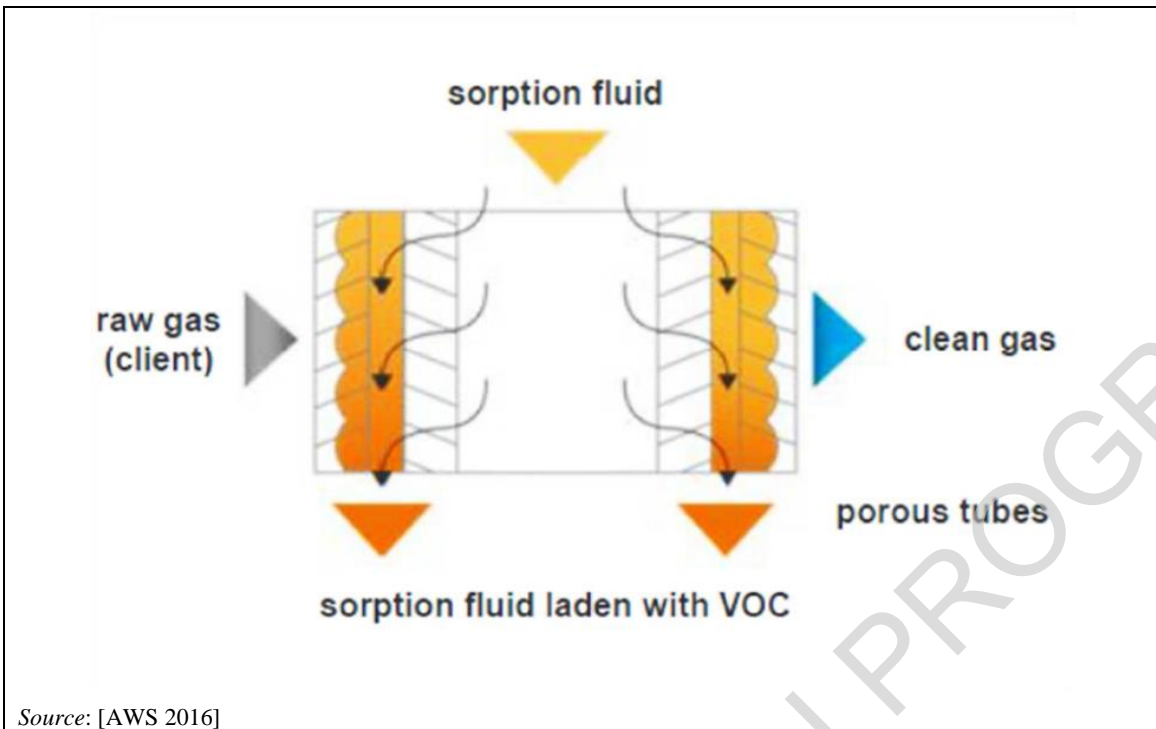


Figure 17.18: Cross-counter current in the absorption unit

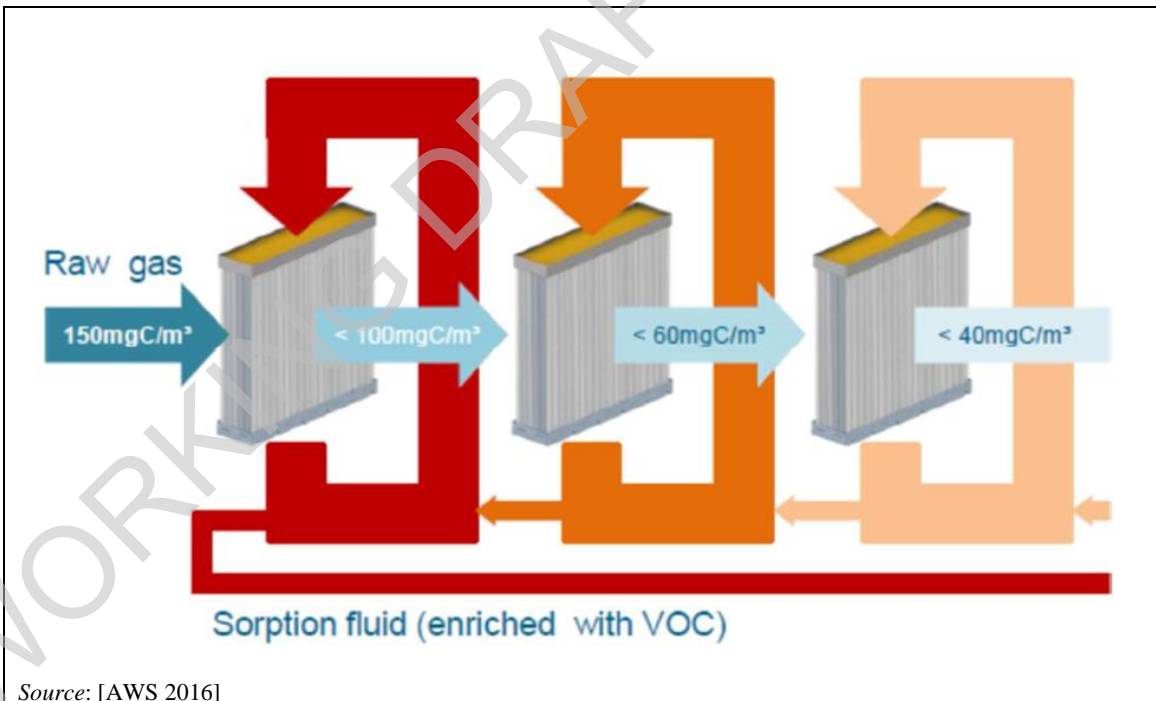
Figure 17.19 illustrates the flow in the Keder tube of the absorption unit.



Source: [AWS 2016]

Figure 17.19:Keder tube in the absorption unit

Figure 17.20 illustrates a filter cascade of absorption units.

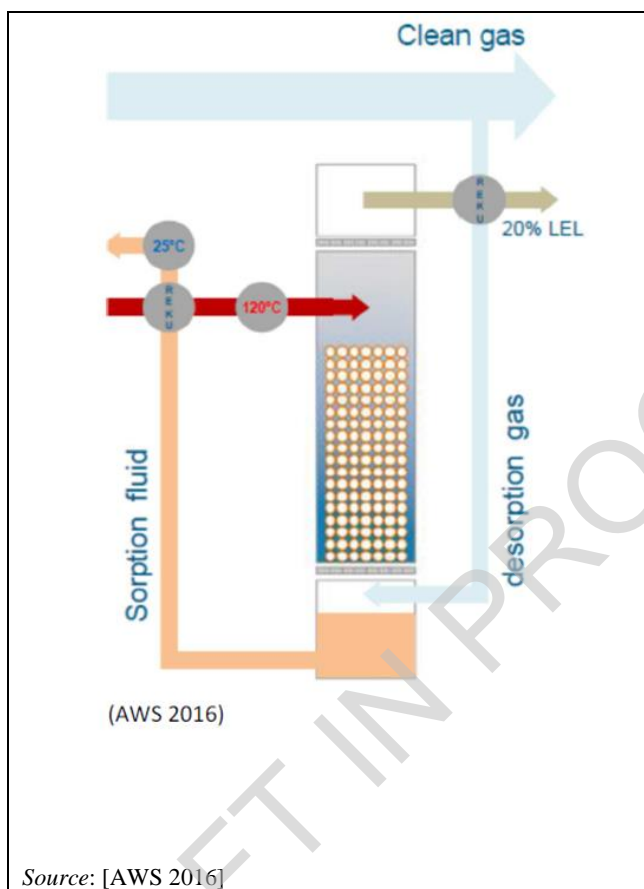


Source: [AWS 2016]

Figure 17.20:Filter cascade of absorption units

Figure 17.21 shows details of the desorption unit. The dark red arrow indicates the inlet of laden fluid originating from the absorption, the light red line shows the return of the fluid to the absorption unit.

Before returning to the absorption unit, the outlet of the hot fluid passes a heat exchange unit to heat-up the incoming fluid. For desorption, the incoming fluid is heated to 130 °C.



**Figure 17.21: Characteristics of the desorption unit**

The absorption plant is used by an automotive manufacturer in Germany to clean the solvent contaminated waste gas from spray booths. In these spray booths car components are painted (mainly plastic parts with a topcoat in series painting). Also, manual coating of parts takes place in the spray booths.

The absorption and desorption in this plant is connected with a condensation (recovery) of the solvents.

Dimensions of the entire filter system: 20.2 m x 9.7 m x 4.7 (L x W x H).

Exhausted air flow: 220 000 m<sup>3</sup>/h (2 lines with 110.000 m<sup>3</sup>/h each)

Absorber: 128 absorption modules

Quantity of absorbents: ~12 700 litres

Automatic control of fill level and temperature

Constant refill of the absorbents

Temperatures: Absorption 25 °C, desorption 130 °C, condensation – 52 °C

Raw gas concentration: max. 130 mg C/Nm<sup>3</sup>

Separation efficiency: (depending on the raw gas load) ~17.8 kg VOC/h

Dimensions of the desorber: 7.3 m x 7.8 m x 6.5 m (L x W x H)

Volume of packed-bed: ~7.9 m<sup>3</sup>

Dimensions of the condensation: 11 m x 1.5 m x 3.8 m (L x W x H)

#### **Achieved environmental benefits**

The waste gas treatment system reduces emissions of volatile organic compounds (VOC).

Solvents that are concentrated in the absorbent can be regained in liquid form through the desorption system in the plant. The desorbed solvents can alternatively be led to a thermal oxidation.

**Environmental performance and operational data**

Measurements method for TOC: FID (EN 12619:2013-04).

Measurement period: 30 minutes.

Waste gas concentration: generally  $< 50 \text{ mg/Nm}^3$ .

Average VOC reduction rate:  $\sim 65 \%$ .

The maximum concentration of the system is up to 25 % of the lower explosion limit (LEL).

In the example plant (applying condensation), waste gas is concentrated with a ratio of  $\sim 55:1$

In case of thermal oxidation, concentration ratio range between  $\sim 30:1$  and  $\sim 100:1$ , depending on the raw gas concentration.

(AWS 2016)

**Cross-media effects****Energy consumption**

The system leads to an additional energy consumption of natural gas and electricity.

The increase of the exhaust fan electricity consumption is calculated separately from electricity consumption of the exhaust fan operating without waste gas treatment system.

Natural gas:

28 m<sup>3</sup>/h corresponding to:  $\sim 280 \text{ kW}_{\text{th}}$

Electricity:

Absorber  $\sim 39 \text{ kW}_{\text{el}}$

Desorber  $\sim 25 \text{ kW}_{\text{el}}$

Cooling of sorption fluid  $\sim 52 \text{ kW}_{\text{el}}$

Condensation  $\sim 359 \text{ kW}_{\text{el}}$

Exhaust air fan (additional)  $\sim 76 \text{ kW}_{\text{el}}$ .

Heat used in the process is provided by hot thermal oil produced with natural gas.

Alternatively, a thermal oxidation system can be installed for combustion of concentrated VOC.

In case of a retrofit, VOC may be directed to existing thermal oxidation plants, which may increase its efficiency where operated with high variations of raw gas concentration. (AWS 2015)

**Applicability**

The waste gas treatment system can be applied in new plants and for upgrading of existing plants. The absorption unit can be implemented in existing ventilation ducts. If not applicable because of restricted space, a separate location of absorption and desorption units is possible.

In case of varying VOC concentrations in the raw gas, the storage capacity of the absorbent can be used to temporally decouple absorption and desorption. (AWS 2015).

**Economics**

Investment and operational costs depend from the waste gas volume and the level of concentration of organic compounds to be treated.

Investment costs: ca. EUR 1.6 million.

Service and waste disposal: EUR 7100/yr.

Refill of process utilities: EUR 57 600/yr.

Energy costs (without fan): EUR 80/h.

Other costs (e.g. refill absorbent): EUR 10/h .

Specific costs for waste gas treatment: EUR 0.041/Nm<sup>3</sup>.

**Driving force for implementation**



The main reason for implementation of the absorption waste gas treatment system are legal requirements. The system can be applied for concentration of VOC where coating substances hinder the application of a zeolite absorption rotor (e.g. UV varnishes, high-boiling agents). The system may be applied where solvent recovery is an objective.

The system is applied where combined heat and power systems are economically viable.

#### **Example plants and supplier**

BMW Group Werk Landshut, Ohmstraße 2, D-84030 Landshut

#### Other plants with the same system

Dr. Ing. h.c. F. Porsche AG, Porscheplatz 1, D-70435 Stuttgart

Porsche Leipzig GmbH, Porschestraße 1, D-04158 Leipzig

Dipl.-Ing. Heinrich Leist Oberflächentechnik GmbH; Ölmühle 5, D-98597 Fambach

Wilhelm Kächele GmbH, Jahnstraße 9, D-73235 Weilheim an der Teck

#### **Reference literature**

(Pfutterer 2016) (Klamser 2016) (Recker 2015) (Walddörfer 2014)

~~Annex 21.9 provides a summary of waste gas treatment techniques (oxidation, adsorption, condensation and biological treatment) and their applicability. A comparison of the removal efficiencies of the most widely used techniques is given for different types of solvents at different inlet concentrations [97, TWG, 2006].~~

#### **17.10.7 Biological treatment**

**TWG please provide additional information on this technique**

Annex 21.9 provides a summary of waste gas treatment techniques (oxidation, adsorption, condensation and biological treatment) and their applicability. A comparison of the removal efficiencies of the most widely used techniques is given for different types of solvents at different inlet concentrations [97, TWG, 2006].

#### **Description**

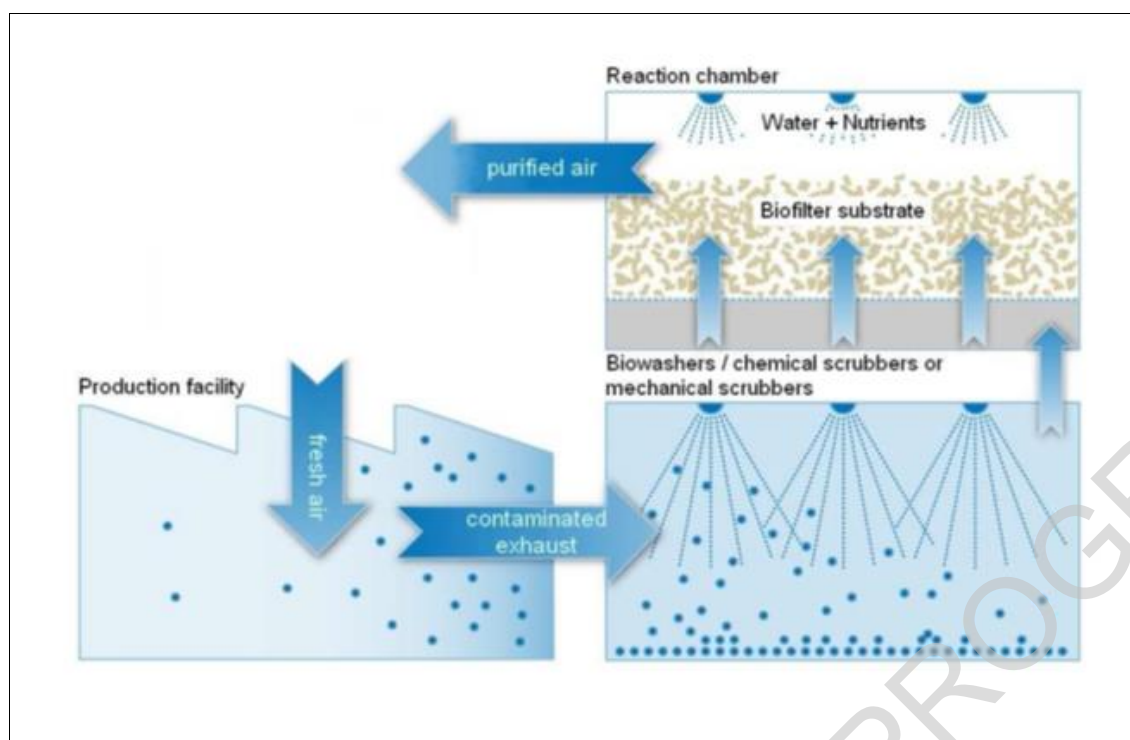
Degradation of organic substances in off-gases by biological processes in a biofilter or bioscrubber.

#### **Technical description**

The biological waste gas abatement system consists of:

- Scrubber for de-dusting and humidification of the waste gas
- Reactor with biofilter substrate for pollutant destruction
- Automatic humidification supplying the microorganisms in the reactor with water and nutrients
- Heat exchanger for heating-up fresh air for the production hall

illustrates the production hall, the scrubber, the reactor and the heat exchanger

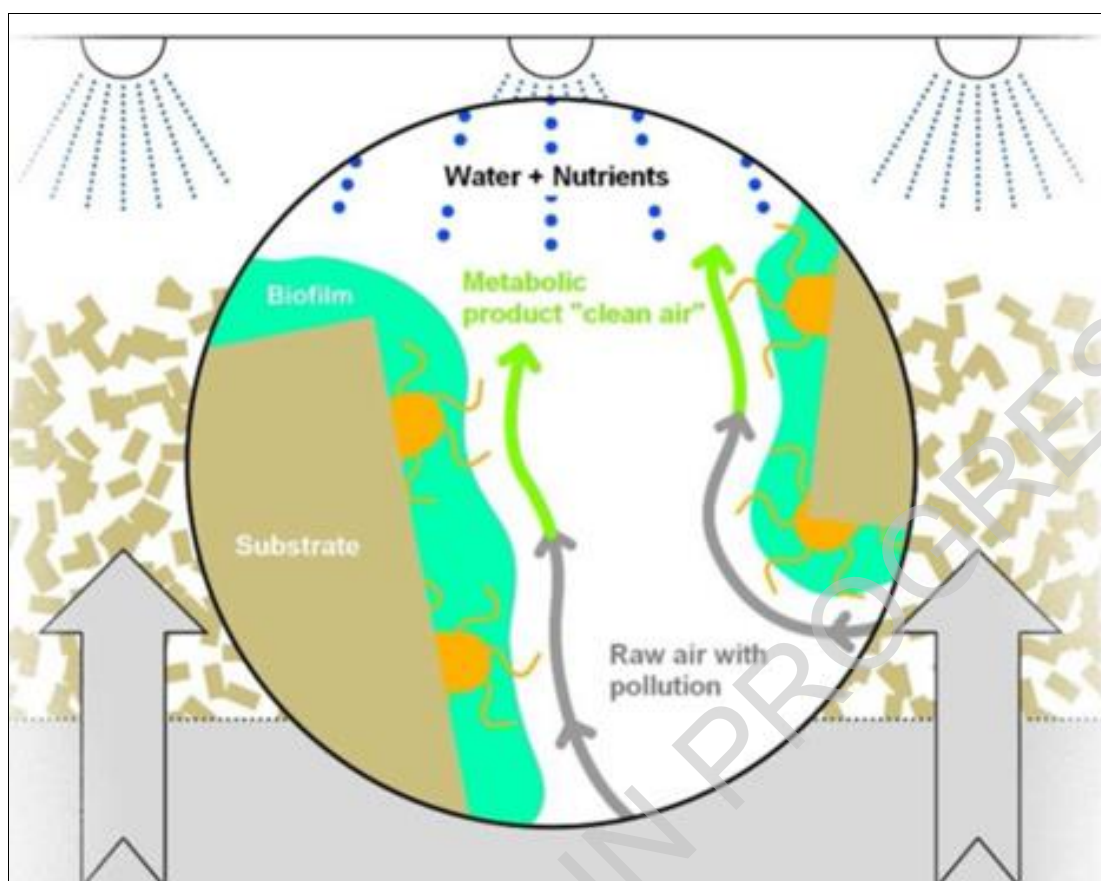


**Figure 17.22: Scheme of the Biological Waste Gas Abatement System**

The scrubber is operated counter-current gas flow. The major part of the scrubber water is circulated. If necessary, a waste water treatment system is installed. It minimizes water consumption and ensures compliance with the local discharge limitations of the sewage system. The biological waste gas abatement system is based on the activity of microorganisms. The organisms biochemically oxidize organic pollutants as well as a part of the inorganic gaseous waste gas compounds. They are converted into non-toxic substances and substances that cannot be smelled.

In the reactor, microorganisms are situated on a solid supporting material. Pollutants contained in the waste gas will be absorbed by the surface of the supporting material (conversion into liquid phase). Pollutants contained in the waste gas will be absorbed on the surface of the supporting material (conversion into liquid phase). By this, they are accessible for the microorganisms. For building-up their own biomass, the microorganisms use pollutants as nutrition and energy source

The reactor contains several layers of packing material. The lower layers consist of coarse-grained material forming the reactor structure. The function of these layers is drainage and air distribution.



**Figure 17.23: Reactor for biological waste gas treatment**

The supporting material is the essential part of the waste gas abatement system. It is adopted to each specific case and consists of organic substances (Figure 17.24). The material is developed and specified by the supplier; it is produced under quality-controlled process conditions.



**Figure 17.24: Biofilter material**

For the upper layer, a specific active mix is used which has shown good results regarding the decomposition of hydrocarbons and odour. The material is highly resistant against biological destruction.

This leads to a long lifetime. The large pores ensure a high biological abatement performance. The activity of the microorganisms and hence the function of the biofilter system is only ensured if the supporting material and the biomass are adapted to the process. Adaptation includes the adaptation of the pore volume and the absorption capacity (buffer capacity). This ensures a high total surface of the biofilter and sufficient retention time.

When the system starts operation, the supporting material will be inoculated with a specific bacteria culture adapted to each waste gas composition. By this, the full performance is achieved in short time.

After adaptation to the organic content of the waste gas, a specific biocenosis is established and kept in balance in the filter material. It differs according to the concentration and the type of waste gas composition.

The metabolism of the bacteria produces water,  $\text{CO}_2$  and biomass. As organic compounds are decomposed, no pollutants are accumulated in the biofilter material. Microorganisms grow rapidly if nutrients supply is optimized. They adapt quickly to changing living conditions. Depending on the type of nutrients, a certain population is developed over time while other microorganisms will not survive.

Load peaks in the waste gas can be stored in the biofilter due to the high buffer capacity of the material. Stored organic compounds will later be decomposed by the microorganisms.

If the TOC load is not sufficient, microorganisms may need to be fed with a mixture of nutrients to ensure a continuous decomposition process and a stable waste gas abatement performance.

~~The waste gas is routed through a biofilter or bioscrubber where microorganisms remove the solvent. The temperature of the waste gas should not exceed 40 °C. The technique is also discussed in the CWW BREF [67, EIPPCB, 2003].~~

**Achieved environmental benefits**

Removal efficiencies of between 75–95 % are achieved.

The biological waste gas treatment system reduces emissions of volatile organic compounds (VOC) and minimizes odour and dust emissions

**Environmental performance and operational data**

Example plant metal coating:

- ▶ Measurements method for TOC: FID (EN 12619:2013-04)
  - ▶ Measurement period: 30 minutes
  - ▶ Raw gas TOC concentration varies between 50 – 300 mgC/Nm<sup>3</sup> (see Figure 3)
  - ▶ Waste gas concentration limits: TOC 50 mg/Nm<sup>3</sup>, dust 3 mg/Nm<sup>3</sup>,
  - ▶ Measurement (7.8.2013): TOC 18,3/27,3/34,9 mg/Nm<sup>3</sup>, dust max. < 0,32 mg/Nm<sup>3</sup>
  - ▶ Measurement (15.7.2015): TOC max. 41,1 mg/Nm<sup>3</sup>, dust max. 0,77 mg/Nm<sup>3</sup>
- Measurement uncertainty (15.7.2015): TOC 6,5 mg/Nm<sup>3</sup>, dust 0,22 mg/Nm<sup>3</sup>

**Cross-media effects****Energy consumption**

The biofilter causes low pressure drop in the waste gas stream and therefore requires only a small power increase of the waste gas ventilator. Additional consumption is about 30 kWh (without conventional electricity consumption for ventilation as this is needed anyway for work place safety).

Due to the biological activity in the biofilter, the waste gas outlet temperature is 2°C higher than the inlet temperature. This energy can be recovered in the subsequent heat exchanger for warming-up fresh air needed in the production halls. In winter, depending on the outside temperature level, about 50 – 75% of the heating energy can be substituted.

**Waste water**

Waste water originates from the operation of the scrubber and the biofilter. The characteristics of the waste water depend from the waste gas composition and the concentration of organic compounds in the waste gas. Usually, discharge to the public sewage system is permitted.

Typical characteristics of the waste water:

- ▶ Waste water temperature: 10°C – 30°C
- ▶ pH about 6 – 8
- ▶ Conductivity: about 500 – 2.000 µS/cm
- ▶ COD: about 400 – 2.000 mg/l

**Waste**

When the supporting material has reached the end of its lifetime, it can be disposed in a biomass incinerator or in a composting plant, as contaminants are not contained but decomposed.

Odour nuisance might occur. Noise levels might increase.

**Operational data**

This technique was tested in a heatset printing plant. However, it was not successful because of the changing solvent concentrations and the variations in, and quantities of, solvents used.

**Applicability**

The biological waste gas treatment system can be applied in new plants and for upgrading of existing plants. The system can be used for treatment of all volatile organic compounds (except methane) usually arising from coating activities.

Biological treatment is applicable for diluted biodegradable streams and, therefore, is often applied for odour control. Requires continuous flow or supplementary feeding. Biofilters are especially suitable for treating low levels of mainly hydrophobic pollutants such as

hydrocarbons and aromatics (e.g. toluene and xylene). Biofilters are especially suitable for pollutants that easily dissolve in water, such as ethers, esters, ketones, alcohols and compounds containing nitrogen.

In the printing industry, the use of this technique is not efficient when the solvent concentration is  $> 1.5 \text{ g/m}^3$ . In heatset, where the concentrations are normally  $1-2 \text{ g/m}^3$ , this technique was tested and the results were negative. In flexible packaging, biological treatment systems have been used meeting an emission limit of  $100 \text{ mg/m}^3$ . It has also been successfully used in the UK in coating operations.

In the painting of furniture and wood sectors in Germany, only one plant applies this technique to reduce the odour nuisance due to solvent emissions.

It is sometimes applied in the manufacturing of abrasive and it is not applied in the automotive or the winding wire industries.

For prolonged shutdown periods, biofilters may require nutrient input to replace the solvent feed.

### Economics

Investment and operational costs depend from the waste gas volume and the level of concentration of organic compounds to be treated.

- Waste gas volume:  
60.000 Nm<sup>3</sup> at full load (about 2.000 h/a)  
30.000 Nm<sup>3</sup> at part load (about 2.000 h/a)
- TOC concentration in waste gas: about 250 mgC/Nm<sup>3</sup>
- Investment costs: about 400.000 €
- Operational costs: about 29.000 €/a
- Maintenance frequency: 1 – 3 h per week
- Specific waste gas treatment costs: 0,016 Cent/m<sup>3</sup>

Operational costs (electricity, water, nutrients, chemicals, biofilter material, waste water disposal) vary due to the heterogeneous waste gas composition, varying waste gas volumes and changing raw gas compositions. The following values are estimates. Costs for disposal of the biofilter material at the end of its lifetime are neglected because it is assumed that energy recovery in a biomass combustion plant can be done without extra costs.

Investment costs are in the range EUR 5 000–20 000 for a capacity of 1 000 m<sup>3</sup>/h waste gas. Operational costs vary from EUR 10–50 per 1 000 m<sup>3</sup> gas treated regarding an installation with a capacity of 5 000 m<sup>3</sup>/h.

The prices below are representative for the Flemish wood industry and based on realistic theoretical working parameters. Equipment suppliers that provided the information stressed that it is impossible to extrapolate the costs of the examples on the basis of flows and VOC loads, so the numbers are purely indicative and valid at the time estimations were made (November 2004).

Flow: 10 000 Nm<sup>3</sup>/h:

- VOC inlet concentration: 500 mg/Nm<sup>3</sup>, VOC emission:  $t: < 90 \text{ mg/Nm}^3$ .
- Price: EUR 135 000 to EUR 250 000.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Metal coating:**

Vallo & Vogler Oberflächenveredlung  
GmbH, Industriestraße 10-14,  
49191 Belm, Germany

**Wood coating:**

Möbelwerkstätten Hunke GmbH,  
Hellweg 110, 33758 Schloß  
Holte-Stukenbrock, Germany

**Reference literature**

(Lütke-Wöstmann 2015)

[14, Amina, et al., 2002] [13, DFIU and IFARE, 2002] [24, ESIG, 2000] [27, VITO, 2003] [12, UBA Germany, 2002] [38, TWG, 2004] [95, CEI BOIS, 2006]

**17.10.8 NO<sub>x</sub> abatement techniques**

*ESVOC propose deletion.*

*TWG please provide additional information*

**17.10.8.1 Optimisation of thermal treatment conditions****Description**

The good design of the combustion chambers, burners and associated devices is combined with optimisation of combustion conditions with or without use of automatic systems and the regular planned maintenance of the combustion system according to suppliers' recommendations

**Technical description**

Measures are taken to maximise the efficiency of VOC destruction while keeping NO<sub>x</sub> emissions as low as possible. This is achieved by a combination of techniques including good design of the combustion equipment, optimisation of the temperature and residence time in the combustion zone, and/or use of an computer-based automatic system to control the combustion efficiency. The system is also regularly maintained according to suppliers' recommendations.

**Achieved environmental benefits**

Reduction of VOC, NO<sub>x</sub> and CO emissions to air in a balanced way.

**Environmental performance and operational information****Cross-media effects****Technical considerations relevant to applicability**

There are techno-economic limitations in the possibilities to improve the combustion chamber design.

**Economics****Driving force for implementation****Example plants**

**Reference literature**

**17.10.8.2 Use of low-NO<sub>x</sub> burners**

*TWG please provide additional information*

**Description**

The peak flame temperature in the combustion chamber is reduced, delaying but completing the combustion and increasing the heat transfer (increased emissivity of the flame). It is combined with increased residence time in order to achieve the desired VOC destruction.

**Technical description**

**Cross-media effects**

**Achieved environmental benefits**

Reduction of NO<sub>x</sub> emissions to air.

**Technical considerations relevant to applicability**

The applicability may be restricted by design and/or operational constraints at existing units.

**Economics**

**Driving force for implementation**

**Example plants**

**Reference literature**



## 17.11 Waste water treatment techniques

*TWG: although the KOM decision was to delete full information on water-based techniques, titles and descriptions have been retained to assist understanding of the emissions to water, water management, etc.*

Waste water treatment may be carried out on-site or off-site. Off-site treatment requires the discharge of waste waters with low concentrations of pollutants. For the STS sector, the treatment of waste water may become a problem when solvent-based products are replaced by water-based alternatives, e.g. when there are soluble solvents, polymers and plasticisers in the waste water. Waste water treatment is described extensively elsewhere, such as in the CWW BREF [67, EIPPCB, 2003] and for this sector in [93, Agences de l'Eau de France, et al., 2002]. More information on waste water treatment techniques for water-based activities can be found in the STM BREF [59, EIPPCB, 2005].

### **Use of decanter centrifuges**

*This technique is now fully described in Section 17.12.8*

### **Continuous discharge of paint sludge**

*This technique is now fully described in Section 17.12.8*

### 17.11.1 Reduction of Cr(VI)

#### **Description**

Conversion of Cr(VI) by a chemical reducing agent to Cr(III) to enable precipitation and removal. This technique is described fully in the STM BREF.

#### **Technical considerations relevant to applicability**

Applicable only to Cr(VI) conversion coatings.

### 17.11.2 pH adjustment and neutralisation

#### **Description**

The adjustment of the pH of waste water by the addition of chemicals. The pH may be adjusted to a specific level for the precipitation of metals (e.g. zinc) or close to neutral (approximately 7) for discharge. This technique is described fully in the STM BREF.

### 17.11.3 Coagulation and flocculation

#### **Description**

Coagulation and flocculation are used to separate suspended solids from waste water and are often carried out in successive steps. Coagulation is carried out by adding coagulants with charges opposite to those of the suspended solids. Flocculation is a gentle mixing stage so that collisions of microfloc particles cause them to bond to produce larger flocs. It may be assisted by adding polymers. More information is provided in the STM BREF and CWW BREF.

### **Coagulation of paint solids in wet cleaners**

*Replaced by section 17.11.3*

**Description:** ~~In spray painting, excess spray (overspray) arises, which in industrial painting plants or spray booths is captured by wet washers. The water needed for cleaning the waste air is circulated in a closed system. Retained overspray or paint sludge has to be removed from this water to maintain proper operation conditions.~~

Overspray from solvent based paints does not usually form a dispersion in water. It therefore forms a flotation coagulate carpet, which is easy to remove. If adsorbents are used for detackifying, the overspray is distributed within the cleaning. It can be removed in a bypass or in the main flow path. Clarification of the water is performed by precipitation and/or flocculation agents.

Water based paints, by contrast, consist very largely of components which will form a suspension in water. The same separation methods are used as for solvent based paints.

**Achieved environmental benefits:** Reduction of water consumption in the circulation system.

**Cross-media effects:** The coagulate has to be removed from the water circuit and must be disposed of.

**Operational data:** No data submitted.

**Applicability:** These techniques are commonly applied in the automotive industry.

**Economics:** Lower costs for fresh water and waste water treatment.

**Driving force for implementation:** The operation of a wet scrubber is necessary for removal of paint particles from the waste air. Continuous coagulation is the best method to maintain a high life time of the water cycle.

**Example plants:** Commonly applied.

**Reference literature:** [38, TWG, 2004]

### 17.11.4 Separation

#### Description

After flocculation (see Section 17.11.3 ), flotation, sedimentation or filtration can be applied to separate the waste water to be discharged from flocculated particles sludges

To separate the coagulated sludge from paint booths from the water either sedimentation or flotation can be applied (see also Section). Flotation and sedimentation are based on the difference in density to achieve a phase separation; for sedimentation, the sludge sinks to the bottom; for flotation, the sludge floats to the surface. The sedimentation process can be improved by the use of a parallel plate or lamella separator, the flotation process is improved by using dissolved air. In the case of sedimentation, the concentrated sludge is pumped from the separator; in flotation, the sludge is scraped mechanically from the top of the liquid in the tank. More information is provided in the STM BREF and CWW BREF.

### 17.11.5 Electroflocculation

#### Description

Electroflotation (EF) is the flotation using electrolytically generated bubbles of hydrogen and oxygen for separating suspended substances from aqueous phases. This effective in separating wastes waters that do not settle well by gravity, such as oily waste water or oil-water emulsion, etc. More information is provided in the STM BREF.

### 17.11.6 Vacuum distillation

#### Description

Vacuum distillation is a technique that uses a vacuum to extract VOCs from the waste water. It is an evaporative recovery system where a vacuum is applied to lower the pressure, so the

distillation can be carried out at a lower temperature. This saves heating costs and also prevents less stable substances from decomposing under the high temperatures that would be required at atmospheric pressure.

### **17.11.7 Biological treatment**

#### **Description**

If the waste water has been subject to preliminary detoxification and its biodegradable fraction is sufficient, biological treatment can be used. More information is provided in the STM BREF and CWW BREF.

### **17.11.8 Filtration (Ultra and nanofiltration and reverse osmosis)**

#### **Description**

With ultra and nanofiltration (UF and NF) and reverse osmosis, the contaminated water passes along a semi-permeable diaphragm under high pressure, which lets through small molecules such as water but not larger particles. The concentration of the contamination increases as the waste water is repeatedly recycled past the filter. The difference in the techniques is the pore size of the filters and therefore the molecules that are filtered out. More information is provided in the STM BREF and CWW BREF.

### **17.11.9 Filter press**

Filter press with woven fabric filters for dewatering sludges, such as the waste phosphate sludge resulting from sedimentation (e.g. in a lamella separator). This technique is described fully in the STM BREF.

## 17.12 Waste minimisation and treatment of wastes containing solvent

Annex III (point 3) to the IED requires the consideration of '*furthering the recovery and recycling of substances generated and used in the process and of waste, where appropriate*'.

The following sections show techniques used to minimise waste through recovery and reuse.

See also Section 17.2.4 on minimisation of raw material consumption and Section 17.12.2 for measures to reduce the loss of raw materials in process waters.

### 17.12.1 Monitoring of waste quantities

#### Description

Annual recording of waste quantities produced by type. Determination of solvent content periodically (at least annually) by using analysis or calculation. Solvent contained in collected waste is one of the parameters of the solvent mass balance.

#### Technical description

#### Achieved environmental benefits

Reduction of solvent emissions in wastes due to better information.

#### Environmental performance and operational information

#### Cross-media effects

#### Technical considerations relevant to applicability

#### Economics

#### Driving forces for implementation

#### Example plants

#### Reference literature

No reference literature provided.

### 17.12.2 Minimisation of the total quantity of wastes

#### 17.12.2.1 Recovery of used solvents from the process and cleaning

#### Description

Used solvents, e.g. used for cleaning, can be treated for reuse, e.g. by filtration or distillation (see Sections 17.12.3.1 and 17.12.3.2). Both recovery and reuse can be done on site or off-site. For example, where pig-clearing systems or purge systems are applied, solvents are used on-site to clean the system after each change of colour – called the purges. Modern paint supply equipment includes recovery of the purge solvents. Solvents can also be disposed of as hazardous waste to an off-site solvent recovery installation. There, the clean solvents are reused, but not necessarily by the same user.

Cleaning can be carried out in washing machines, where the solvent is recovered and reused internally (see Section 17.9). Halogenated VOCs can be used for this technique, in conjunction with closed storage and waste systems.

**Achieved environmental benefits**

Reduced amounts of hazardous waste and reduced consumption of fresh solvents. By reusing the hazardous waste (in this case solvent), its life cycle is expanded.

In the automotive industry, typically 80–90 % cleaning and purge solvents can be recovered, either on site or off site, for reuse.

**Cross-media effects**

Noise levels might increase. Storage risk increased for hazardous materials.

**Operational data**

For filtration and distillation in an economical manner, generally large quantities (several tonnes at a time) are required and are usually contracted out. This implies storage of large amounts of both clean and used solvents. There should be adequate storage for both receiving used solvents waiting to be removed and for the returned clean solvent: the amounts should be equal if usage remains unchanged.

In coil coating processes, solvents from waste paints are commonly recovered and reused in cleaning activities. The remaining solid waste is usually incinerated off-site.

**Applicability**

Applicable in plants using large quantities of solvents. Recovery of cleaning agents is commonly applied in:

- publication gravure, heatset offset, and flexo and packaging gravure plants. However, only in publication gravure and offset plants using more than 200 litres cleaning agents a week;
- the coating and printing of metal packaging;
- furniture painting, e.g. in the coating of wooden kitchen and bathroom furniture;
- the winding wire industry;
- the automotive industry.

The cleaning of purge solvents is applicable in all industries applying piping systems, e.g. paints or inks supply and is commonly applied in the automotive industry.

Care must be taken to ensure that solvents recovered by distillation or filtration (or any other method) are only used where technical specifications are fulfilled. They can alternatively be used for other applications, or reworked to meet the specification required (although this is usually more expensive than buying fresh solvent).

**Economics**

A saving will be incurred because of reduced consumption of solvents and a reduced amount of hazardous waste. In large plants, the savings will approximately outweigh the investment. For example, the investment costs for the recovery of cleaning agents might be in the range of EUR 3 000–150 000, depending on, e.g. size, tank capacity and automation.

Reusing hazardous used solvents is a cost-effective activity. The utilisation of hazardous used solvents is productive for the company that generates used solvents, because the company does not have to pay for the disposal of hazardous waste. The company that processes the used solvents gets the necessary amount of input solvent cheaply, and the end user who needs processed used solvents in its manufacturing processes gets the raw material at a competitive price.

The installation of a typical solvent recovery system in the automotive industry costs EUR 0.4 million per spray booth.

**Driving force for implementation**

Solvent recycling and VOC emission reduction.

**Example plants**

Ford plants in Europe.

**Reference literature**

[4, Intergraf and EGF, 1999] [13, DFIU and IFARE, 2002] [26, CITEPA, 2003] [68, ACEA, 2004] [38, TWG, 2004] [78, TWG, 2005]

**17.12.2.2 Recovery of used solvents from wipes**

*ESVOC propose deletion. EIPPCB –according to questionnaires used in some plants*

**Description**

The majority of solvents in wipes are removed by draining by gravity, a wringer, or a centrifuge prior to transport.

This technique is an answer to the bad practice of using too much solvent and pouring the excess used solvents over the wipes in order not to have to dispose of them separately.

**Achieved environmental benefits**

The recovered solvents can be used again for cleaning, or if too dirty, distilled and reused (see Section 17.12.3.2). Less weight has to be transported. Reduced emissions during storage and transportation.

**Cross-media effects**

Emissions on-site from the handling required for removing the solvents from the wipes. Noise levels might increase.

**Operational data**

Commonly applied in the printing industry in the US.

**Applicability**

Applicable to all printing plants using solvent wipes. The wipes might be reusable or disposable.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[18, US EPA et al., 2003] [38, TWG, 2004]

**17.12.3 Treatment of used solvents for reuse**

**17.12.3.1 Filtration**

See also Section 17.12.3.1.

**Description**

Dirty cleaning solutions, e.g. of HBS or VCA, can be filtered. The solvents can be reused and the water residue can normally be discharged to the municipal waste water system.

**Achieved environmental benefits**

Less waste water and less use of fresh solvents.

**Cross-media effects**

Filtration requires energy and the water residue is discharged. Noise levels might increase. The impact upon the aquatic environment has not been considered sufficiently. Any dissolved HBS or VCA will drastically affect the chemical oxygen demand and biological oxygen demands of the water being discharged to the municipal waste water system.

**Operational data**

Experiments are being carried out in the Netherlands with low volatility cleaning agents in cleaning machines for flexible packaging. Filtration and reuse of these cleaning agents is an important part of these experiments.

**Applicability**

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[18, UBA Germany, 2003] [38, TWG, 2004]

**17.12.3.2 Distillation**

See also Section 17.12.3.2.

**Description**

Solvent-based waste such as inks, paints, paints and adhesives can be distilled to recover the solvent and to reduce the amount of hazardous waste. Special purpose distillation equipment exists.

**Achieved environmental benefits**

The amount of hazardous waste is reduced and the solvent can be reused, e.g. for cleaning.

**Cross-media effects**

Distillation requires energy. However, compared to incineration, which creates CO<sub>2</sub> and also uses energy, it is likely that distillation and reuse saves energy. Noise levels might increase.

**Operational data**

The distillation equipment must be installed and operated with care. Cleaning agents with a high flashpoint generally also have a high boiling point. For these solvents, only vacuum distillation equipment can be applied (see Section 17.11.6); in these situations membrane filtration may be used (see Section 17.11.8). It is reported that relatively small vacuum distillation units (50 litres) are readily available. Furthermore, membrane filtration can be expensive and many of the solvents used can attack the membrane.

Cleaning machines that have distillation equipment attached are available.

In publication gravure plants (where toluene is the sole ink diluter) the equipment for the distillation of cleaning agents may be, if suitable, also used for waste ink. Distilling waste inks only is not cost-effective.

### **Applicability**

Applicable in new and existing installations. Applicable to solvent-based inks and adhesives.

No distillation of the waste ink is carried out in publication gravure because only four colours are used and there is little waste ink.

In packaging gravure, distillation of waste inks is used decreasingly because there is less waste inks due to the application of automated mixing of inks (see Section 17.2.4.1).

Where on-site distillation is not cost effective, external distillers can be used, e.g. in publication gravure.

Used in the automobile industry if the recovered solvents can be used for processes with a lower quality requirement, such as general cleaning.

### **Economics**

Investment costs start at EUR 10 000 for smaller vacuum distillation plants, depending on, e.g. size, tank capacity and automation. There is an additional cost if the existing equipment for the distillation of cleaning agents can be used.

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

### **Reference literature**

[4, Intergraf and EGF, 1999] [14, DFIU and IFARE, 2002] [22, ECCA, 2004] [38, TWG, 2004] [78, TWG, 2005]

## **17.12.4 Disposable cleaning wipes**

*ESVOC propose deletion. EIPPCB –according to questionnaires is used in some plants*

### **Description**

Cleaning can be done with disposable and reusable wipes. Once dirty, the disposable wipes are thrown away and treated as hazardous waste. This normally implies incineration.

Disposable wipes are generally made of synthetic fibres. Per unit of weight, they can contain many times more cleaning agent and dirt than reusable wipes. After use, they are incinerated together with their contamination. Since disposable wipes are light, the incineration of the sludge from the cleaning of reusable wipes offers little advantage over incineration of completely disposable wipes.

Disposables have far better adsorption properties than reusable wipes thus less weight and volume is needed. The amount of transportation involved is, consequently, also much smaller.

### **Achieved environmental benefits**

There is no clear environmental difference between reusable and disposable wipes. There is no environmental preference for either.

### **Cross-media effects**

Raw materials are consumed in the production of disposables.



**Operational data**

An important factor in the choice for disposable wipes is the damage that may be done to very sensitive surfaces such as offset plates and gravure cylinders by a reusable wipe that is not completely free of contamination from previous uses.

**Applicability**

Disposable wipes are commonly used in all types of industries, e.g. in the printing and coil coating industry.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[4, Intergraf and EGF, 1999] [18, UBA Germany, 2003] [22, ECCA, 2004] [38, TWG, 2004] [78, TWG, 2005]

**17.12.5 Reusable cleaning wipes**

*ESVOC propose deletion. EIPPCB –according to questionnaires is used in some plants*

**Description**

Cleaning can be done with disposable and reusable wipes. Reusable wipes are normally rented. Once dirty, they are returned to the rental company, where they are washed and put back into circulation.

Reusable wipes are made of natural textile fibres. After use, they are washed with solvents and then dried. The contaminated solvent is distilled and the sludge is incinerated as hazardous waste. The washing, drying and distillation processes for reusable wipes give rise to solvent emissions.

Since reusable wipes are far less adsorbent than disposables, a far greater weight and volume is needed. The amount of transportation involved is consequently larger for the same amount of cleaning. However, reusable wipes generate less waste than disposable wipes.

**Achieved environmental benefits**

There is no clear environmental difference between reusable and disposable wipes. There is no environmental preference for either.

**Cross-media effects**

No data submitted.

**Operational data**

Reusable wipes are stronger and thicker than disposable wipes. This makes them fit for use in situations where manual force and repetitive movement are necessary to clean the object. This force is not used on delicate surfaces.

**Applicability**

Reusable wipes are commonly used in all types of industries, e.g. in the printing and coil coating industry.

Reusable cleaning wipes are too hard for the finishing of wooden workpieces.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[4, Intergraf and EGF, 1999] [18, UBA Germany, 2003] [22, ECCA, 2004] [38, TWG, 2004]

**17.12.6 Reusable containers**

**Description**

Many raw materials are supplied in reusable containers, such as IBC containers with a capacity of approximately 1 tonne, or standard 200 litre metal drums, etc. These containers can be returned for reuse or reused for containing solvents. Incorporation of a liner that is unreactive to the contents and can be disposed of can eliminate the damage to the 200 litres open top drum and make reuse easier.

**Achieved environmental benefits**

Reduced waste.

**Cross-media effects**

Before reuse, the containers need to be cleaned, normally off site.

**Operational data**

Large offset printing plants apply a direct supply of ink by piping systems. Solvents used as cleaning agents are also commonly contained in reusable containers. Less waste containers and large containers makes direct ink supply to the presses via piping systems possible.

A disadvantage might be that the reuse of empty ink and solvent containers require the return of these containers to the manufacturers. As the trade in inks is international, empty metal containers would have to be collected, stored and then shipped across Europe.

**Applicability**

Applicable to all plants using large quantities of materials.

In heatset web offset printing, the standard colours of offset inks are supplied in reusable containers.

In flexible packaging, the many different colours used restrict its applicability. The amount per colour does not warrant sending containers back to the supplier, with the possible exception of white ink, some paints and some adhesives. The containers in which the inks have been supplied are reused in house. They are used to mix colours, to dilute inks and to transport the inks to the presses. They are frequently cleaned and reused many times over.

Reusable bulk containers for paint are commonly applied in coil coating plants. They are also supplied in the winding wire industry and sent back to the supplier after use.

**Economics**

Ink and solvents supplied in large quantities in reusable bulk containers are often cheaper and less waste has to be disposed of.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[4, Intergraf and EGF, 1999] [22, ECCA, 2004] [38, TWG, 2004] [78, TWG, 2005]

**17.12.7 Regeneration of used activated carbon**

Adsorption may be used to treat waste gases (see Section 17.10.6.3). When the surface of the adsorbent has adsorbed nearly as much as it can, the efficiency of adsorption decreases. The adsorbent is then usually regenerated by desorbing the retained solvents (and other materials). This may be carried out on-site (see Section 20.11.6.1) or off-site (see Section 20.13.7.2, below). The adsorbent also collects materials that are not desorbed, and these occupy increasing proportions of the surface area, leading to a decrease in the removal efficiency of target pollutants. The adsorbent may be regenerated by heat treatment (see Section 20.13.7.1)

**17.12.7.1 On-site recovery of the used activated carbon and other adsorbents****Description**

As well as solvents in the waste gases, the carbon also adsorbs materials that are not desorbed in the regeneration/solvent removal process (see Section 20.11.6.1), such as non-recoverable solvents, retarders and plasticisers. This causes the efficiency of used adsorbent to fall after a period of time. The adsorbent can, in certain cases, be regenerated on-site or off-site by heat treatment.

**Achieved environmental benefits**

Prolongs the life of the adsorbent.

**Cross-media effects**

Energy used in regeneration. The heat treatment may give rise to emissions from the adsorbed materials and their breakdown products.

**Operational data**

No data submitted.

**Applicability**

No data submitted.

**Economics**

There are savings in purchasing fresh adsorbent; however, the energy costs need to be considered.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[78, TWG, 2005].

### 17.12.7.2 Off-site regeneration/solvent removal of the used activated carbon and other adsorbents

#### Description

Waste gases loaded with solvents are routed through an adsorber with activated carbon or other adsorbent. This might be a canister containing the adsorbent which is placed on the vent. Once saturated, the canister with the adsorbent is returned to the supplier for regeneration. Where the waste gas contains several different solvents, recovery of the solvents is a complicated process. Regeneration in this case can be done more effectively by specialised companies.

#### Achieved environmental benefits

Reduced adsorbent consumption.

#### Cross-media effects

Regeneration off-site requires a type of adsorbent that is strong enough to be transported.

#### Operational data

No data submitted.

#### Applicability

Canisters are especially suitable for small flowrates with low loading; high loading would require frequent cartridge changes. These are often used to abate odours.

Especially suitable for plants applying one type of solvent.

Not applied in vehicle paint shops, but in other workpiece paint shops in the automotive industry.

#### Economics

For an airflow of 7 000 m<sup>3</sup>/h and < 20 t/yr of solvents, costs are over EUR 100 000 per year. However, for small flows, applying canisters is a low investment system.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

[14, Aminal, et al., 2002] [14, DFIU and IFARE, 2002] [24, ESIG, 2000] [37, Jansen, 2005] [38, TWG, 2004] [78, TWG, 2005]

### 17.12.7.3 Incineration of the used activated carbon or other adsorbents

#### Description

If the activated carbon or other adsorbents cannot be regenerated, they are usually disposed of by incineration.

#### Achieved environmental benefits

Carbon or other adsorbents that are only used once can generally adsorb more solvents than those that can be regenerated.

#### Cross-media effects

The total amount to be incinerated is greater because not only the solvent, but also the carbon is incinerated, and consequently more carbon is consumed.

**Operational data**

No data submitted.

**Applicability**

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[14, Aminal, et al., 2002] [14, DFIU and IFARE, 2002] [24, ESIG, 2000] [78, TWG, 2005].

**17.12.8 Waste water sludges**

Techniques for treating and managing waste water sludges are described in more detail in the STM BREF [59, EIPPCB, 2005] and in the CWW BREF [67, EIPPCB, 2003], as well as in specialist texts such as [93, Agences de l'Eau de France, et al., 2002].

**17.12.8.1 Centrifuges****Description**

Centrifuges are used for enforced draining of paint sludge. Paint sludge is disposed of, whereas the fluid is usually fed back into the waste water treatment process.

**Achieved environmental benefits**

Easier handling of waste. Less solid or sludgy waste to dispose of.

**Cross-media effects**

No data submitted.

**Operational data**

Water contents of 50–70 % can be reached.

**Applicability**

These techniques are applied in the automotive industry if the water content after sedimentation or flotation is still too high. In the case of phosphate sludge, filter presses can be used instead.

**Economics**

Lower costs for transport and disposal of paint sludge.

**Driving force for implementation**

Cost reduction, legal requirements.

**Example plants**

VW, Emden, Germany.

**Reference literature**

[59, EIPPCB, 2005] [38, TWG, 2004]

### 17.12.8.2 Filter press

#### **Description**

Separated phosphate sludge from sedimentation (such as from a lamella separator) is often dewatered using filter presses with woven fabric filters.

#### **Achieved environmental benefits**

Easier handling and disposal of the waste. Reduced waste volume and weight.

#### **Cross-media effects**

No data submitted.

#### **Operational data**

Water contents of 40–60 % can be reached.

#### **Applicability**

These techniques are commonly applied in the automotive industry.

#### **Economics**

Lower costs for transport and disposal of paint sludge.

#### **Driving force for implementation**

Cost reduction, legal requirements.

#### **Example plants**

Commonly applied.

#### **Reference literature**

[59, EIPPCB, 2005] [38, TWG, 2004]

#### **Dust abatement**

*ESVOC propose deletion*

*For techniques to reduce dust or particle emissions from spray booths, see Section 17.10.4*

## 17.13 Odour abatement

Many processes using solvent have odour impacts. However, in-process and end-of-pipe waste gas measures to reduce solvent emissions as well as the installation of high stacks for waste gas emissions also resolve these, see Sections 17.6, Substitution, and 17.10, Waste gas treatment).

### 17.13.1 Odour management plan

#### Description

An odour management plan (OMP) is part of the environmental management system (EMS) of the installation (see Section ) and includes elements to prevent or reduce odorous nuisances.

#### Technical description

The OMP includes:

- a protocol containing actions and timelines;
- a protocol for conducting odour monitoring;
- a protocol for response to identified odour incidents;
- an odour prevention and reduction programme designed to identify the source(s), to measure/estimate odour exposure, to characterise the contributions of the sources, and to implement prevention and/or reduction measures.

#### Achieved environmental benefits

Prevention or reduction of the emissions of those odorous releases that may be offensive and detectable beyond the boundaries of the site

#### Technical considerations related to applicability

The technique is applicable to new and existing plants where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

### ~~Venting tanks during deliveries of solvent-based materials~~

*ESVOC propose deletion. EIPPCB: merged in section 17.2.3.3*

~~**Description:** During deliveries of materials containing solvent, the vapour in any pipe line and the head space of the tank are vented or they may be back vented (see Section 0). Where back venting is not used or impracticable, for example: due to long pipe runs, back pressure, or contractual agreements over deliveries, and displaced air vents are used, they should be sited in such a way as to prevent the arising of offensive odour beyond the site boundary.~~

~~**Achieved environmental benefit:** No data submitted.~~

~~**Cross media effects:** No data submitted.~~

~~**Operational data:** No data submitted.~~

~~**Applicability:** No data submitted.~~

~~**Economics:** No data submitted.~~

~~**Driving forces for implementation:** No data submitted.~~

~~**Example plants:** Commonly applied.~~

~~**Reference literature:** [121, UK, et al., 2003] [78, TWG, 2005] [112, Verspoor, 2006]~~

## Noise abatement

*ESVOC propose delete. EIPPCB – merge in BAT 1*

**Description:** It is good practice to reduce noise from the installation so impact upon sensitive targets is not significant. Noise can be generated:

- in process, especially by rapidly moving machinery (such as folders and cutters in printing processes, equipment for stamping and drawing, fast moving conveyors, etc.)
- by associated activities and equipment such as air compressors, air/waste gas extraction systems, waste gas oxidisers, etc.

Noise can be eliminated or reduced by:

- in process and engineered solutions:
  - engineering noise control measures where required, such as installation of silencers to large fans, use of acoustic enclosures
  - avoiding selection of equipment with high or tonal noise levels, etc.
  - enclosing presses and other sources of noise
- management systems:
  - effective preventative maintenance on noisy plants, e.g. replacing bearings on fan motors
  - delivery transport can also have an impact locally, and can be managed by reducing deliveries and/or managing delivery times
  - effective plant operation includes closure of delivery bay and workplace doors.

**Achieved environmental benefits:** Reduced noise. Effective preventative maintenance on fans and motors can reduce energy demand.

**Cross-media effects:** Use of silencers can lead to an increase in energy as pressure drops increase.

Closing bay doors can increase demands on internal ventilation and cooling.

**Operational data:** Site specific.

**Applicability:** Applicable to new and existing plants such as heatset and publication gravure (where folders/cutters are usually enclosed), but not in the web printing process (where the product is on rolls).

**Economics:** Case specific, but there is usually no payback. Increased cost of ventilation with delivery bay and workplace doors closed.

**Driving forces for implementation:** Prevention of noise complaints. Compliance with occupational health legislation (which often results in noise sources being enclosed preventing high levels outside the installation).

**Example plants:** Widely used.

**Reference literature:** [61, Eurofer, 2003] [78, TWG, 2005]



## 18 BEST AVAILABLE TECHNIQUES (BAT) CONCLUSIONS FOR SURFACE TREATMENT USING ORGANIC SOLVENTS AND THE PRESERVATION OF WOOD AND WOOD PRODUCTS WITH CHEMICALS

*[This section is based on standard text and has been completely rewritten compared to the original STS BREF]*

### Scope

These BAT conclusions concern the following activities specified in Annex I to Directive 201/75/EU:

- 6.7: Surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with an organic solvent consumption capacity of more than 150 kg per hour or more than 200 tonnes per year.
- 6.10: Preservation of wood and wood products with chemicals with a production capacity exceeding 75 m<sup>3</sup> per day other than exclusively treating against sapstain.

These BAT conclusions do not address the following:

- Dressing;
- Waterproofing of textiles by means other than as a continuous film using solvents; printing; sizing and impregnation of textiles;
- Production of wood-based panels, laminate boards and chipboard
- Conversion of rubber;
- Manufacturing of coating mixtures, paints, inks and adhesives, and pharmaceutical products;
- Chemical wood modification and hydrophobisation (e.g. using resins);
- Sap stain treatment;
- Ammonia treatment;
- On-site combustion plants where the flue-gases are used to dry wood direct;
- On-site combustion plants (including engines) not generating hot gases for directly heated dryers.

Other BAT conclusions and reference documents which may be of relevance to the activities covered by these BAT conclusions are the following:

- Emissions from Storage (EFS);
- Energy Efficiency (ENE);
- Surface treatment of metals and plastics (STM);
- Monitoring of Emissions to Air and Water from IED installations (ROM);
- Economics and Cross-Media Effects (ECM).

WORKING DRAFT IN PROGRESS

## Definitions

For the purposes of these BAT conclusions, the following definitions apply:

Term	Definition
Base coat	Paint which, when applied to a substrate, determines the colour and the effect (e.g. metallic, pearl)
Clear coat	Coating material which, when applied to a substrate, forms a solid transparent film having protective, decorative or specific technical properties
CMR VOCs	VOCs classified as carcinogenic, mutagenic or toxic to reproduction under Regulation (EC) No 1272/2008, and which are assigned to carry the hazard statements H340, H350, H350i, H360D or H360F, including mixtures which are classified as such because of their content of VOCs
CO	Carbon monoxide
COD	Chemical oxygen demand. Amount of oxygen needed for the total chemical oxidation of the organic matter to carbon dioxide. COD is an indicator for the mass concentration of organic compounds
Continuous measurement	Measurement using an 'automated measuring system' permanently installed on site
Chromium total (Cr <sub>total</sub> )	Chromium (total). In waste waters, the sum of chromium and its compounds, dissolved or bound to particles, expressed as Cr
Hexavalent chromium (CrVI)	Hexavalent chromium, expressed as Cr(VI), includes all chromium compounds where the chromium is in the oxidation state +6 (dissolved or bound to particles)
DMF	N,N-Dimethylformamide
Dust	Total particulate matter (in air)
DWI	Draw and wall-ironed cans (a type of can product in the metal packaging industry)
EB	Electron beam curing of specific inks and paints
Emission factors	Coefficients that can be multiplied by known data such as plant/process data or throughput data to estimate emissions
EMS	Environmental management system
Existing plant	A plant that is not a new plant
Existing unit	A unit that is not a new unit
Fugitive emissions	Fugitive emissions as defined in Article 57(3) of Directive 2010/75/EU
Hexavalent chromium	Hexavalent chromium, expressed as Cr(VI), includes all chromium compounds where the chromium is in the oxidation state +6.
IED	Industrial Emissions Directive (Directive 2010/75/EU on industrial emissions - integrated pollution prevention and control)
IPA	Isopropyl alcohol: propan-2-ol (also called isopropanol)
IR	Infrared radiation (IR) (used as a drying technique)
LEL	Lower explosive limit – the lowest concentration (percentage) of a gas or vapour in air capable of producing a flash of fire in the presence of an ignition source. Concentrations lower than LEL are 'too lean' to burn. Also called lower flammable limit (LFL)
New plant	A plant first permitted on the site of the installation following the publication of these BAT conclusions or a complete replacement of a plant following the publication of these BAT conclusions
New unit	A unit first permitted following the publication of these BAT conclusions or a complete replacement of a unit following the publication of these BAT conclusions
Nickel (Ni)	Nickel. In waste waters, the sum of nickel and its compounds, dissolved or bound to particles, expressed as Ni
NMP	N-Methyl-2-pyrrolidone
NO <sub>x</sub>	The sum of nitrogen monoxide (NO) and nitrogen dioxide (NO <sub>2</sub> ), expressed as NO <sub>2</sub>
Off-gas	The gas extracted from a process, equipment, or area which is directed either to treatment or discharged directly to air
Organic solvent	Organic solvent as defined in Article 3(46) of Directive 2010/75/EU
OTNOC	Other than normal operating conditions
PAH	Polycyclic aromatic hydrocarbons

Primer coat	Paint formulated for use as a layer on a prepared surface, to provide good adhesion, protection of any layers below and filling of surface irregularities
Plant	In this document, a part of an installation that carries out an activity listed in Annex 1, 6.7 or 6.10 of Dir. 75/2010 and any other directly associated activities on the same part of the installation which have an effect on consumptions and emissions. Plants may be new plants or existing plants and may consist of one or more units
PU	Polyurethane
PVC	Polyvinyl chloride
RTO	Regenerative thermal oxidation; WGT using regenerative thermal oxidation
SB	Paint, ink or other coating material using solvent(s) as the carrier
SB-mix	Solvent-based coating where one of the other coating layers is water-based (WB)
Sector	Any of the surface treatment activities that are part of activities 6.7 and 6.10 of Annex I to Directive 2010/75/EU and are referred to in Sections 1.1 and 1.2 of these BAT conclusions
Sensitive receptor	Area which needs special protection, such as: - residential areas; - areas where human activities are carried out (e.g. neighbouring workplaces, schools, day-care centres, recreational areas, hospitals or nursing homes)
Solvent	In this document, 'solvent' refers to 'organic solvent' unless otherwise stated
Solvent mass balance (SMB)	A mass balance exercise conducted at least on an annual basis according to Part 7 of Annex VII, Directive 2010/75/EU
STM	Surface treatment of metals and plastics (using water-based processes)
STS	Surface treatment using organic solvents
SVHC	Substances of very high concern that are subject to the authorisation procedure under Regulation 1907/2006/EC (the REACH Regulation)
Surface run-off water	Surface run-off water is generated by rain, snowmelt or cleaning events; it is the water that flows over land or impervious surfaces, such as paved streets and storage areas, rooftops, etc. and does not soak into the ground. It can, in exceptional cases (OTNOC), comprise firefighting water as well
TO	Thermal oxidation; WGT using thermal oxidation
TOC	Total organic carbon, expressed as C (in water or in gases)
Total emissions	The sum of fugitive emissions and emissions in waste gases as defined in Article 57(4) of Directive 2010/75/EU
Treatment chemicals	Chemicals used in wood preservation such as biocides, chemicals used for waterproofing (e.g. oils, emulsions, etc.), fire retardants and also chemicals used in chemical wood modification (CWM) or hydrophobisation (like acetic anhydride, furfuryl alcohol, silicones)
TSS	Total suspended solids (in water)
Unit	A segment/subpart of a plant in which a specific process or operation is carried out (e.g. paint line, printing press, coil coating line). Units can be new units or existing units
UV	Ultraviolet light used in curing specific inks and paints
VOC	Volatile organic compound as defined in Article 3(45) of Directive 2010/75/EU
WB	Paint, ink or other coating material in which water replaces all or part of the solvent content
Waste gases (WG)	Waste gases as defined in Article 57(2) of Directive 2010/75/EU
Wet-on-wet	Technique whereby a further coat is applied before the previous one has dried, and the composite film then dries as a single entity
WGT	Waste gas treatment
WWTP	Waste water treatment plant
Zinc (Zn)	Zinc. In waste waters, the sum of zinc and its compounds, dissolved or bound to particles, expressed as Zn

## GENERAL CONSIDERATIONS

### Best Available Techniques

The techniques listed and described in these BAT conclusions are neither prescriptive nor exhaustive. Other techniques may be used that ensure at least an equivalent level of environmental protection.

Unless otherwise stated, these BAT conclusions are generally applicable.

[NOTE: Whilst cross-references are provided to other parts of this document in order to aid the work of the TWG, they will not be included in the final BAT conclusions themselves. Such cross-references are consequently displayed in italic blue between square brackets.]

[NOTE: Please note that, in order to avoid repetition, this section contains general considerations that are essential to the understanding of the BAT conclusions taken as a stand-alone document, such as:

- reference conditions for air emissions (e.g. dry gas, standard temperature/ pressure, oxygen concentration);
- averaging periods;
- sampling times;
- conversions to reference conditions;
- adopted units of measures.]

### Emission levels associated with the best available techniques (BAT-AELs)

#### BAT-AELs for total and fugitive VOC emissions

For total VOC emissions, the emission levels associated with the best available techniques (BAT-AELs) are given in these BAT conclusions:

- as a specific emission load calculated on an annual basis by the division of the total emissions (as calculated by the solvent mass balance) by a sector-dependent suitable (depending on the sector) production input (or throughput) parameter; or
- as a percentage of the total organic solvent input, calculated on an annual basis as per Part 7.3 (b)(i) of Annex VII to Directive 75/2010/EU.

For fugitive VOC emissions, the emission levels associated with the best available techniques (BAT-AELs) are given in these BAT conclusions as a percentage of the total solvent input and are calculated on an annual basis as per Part 7.3 (b)(i) of Annex VII to Directive 75/2010/EU.

#### BAT-AELs for emissions to air in waste gases

Emission levels associated with the best available techniques (BAT-AELs) and indicative levels in waste gases emitted to air given in these BAT conclusions refer to concentrations, expressed as mass of emitted substance per volume of waste gas under the following standard conditions: dry gas at a temperature of 273.15 K and a pressure of 101.3 kPa, without correction for O<sub>2</sub> and expressed in the unit mg/Nm<sup>3</sup>.

For averaging periods of BAT-AELs and indicative emissions levels for emissions in waste gases to air, the following **definitions** apply.

Type of monitoring	Averaging period	Definition
Continuous monitoring	Daily average	Average over a period of one day based on valid hourly or half-hourly averages
Periodic monitoring	Average over the sampling period	Average value of three consecutive measurements of at least 30 minutes each <sup>(1)</sup>

<sup>(1)</sup> For any parameter where, due to sampling or analytical limitations, 30-minute measurement is inappropriate, a more suitable measurement period may be employed.

### BAT-AELs for emissions to water

Emission levels associated with the best available techniques (BAT-AELs) for emissions to water given in these BAT conclusions refer to concentrations, expressed as mass of emitted substance per volume of water, and expressed in mg/l. The BAT-AELs refer to daily average values, i.e. 24-hour flow-proportional composite samples. Time-proportional composite samples may be used provided that sufficient flow stability is demonstrated.

All BAT-AELs for emissions to water apply at the point where the emission leaves the plant.

### Other environmental performance levels

#### Specific energy consumption (energy efficiency) levels associated with the best available techniques (BAT-AEELs)

The environmental performance levels related to specific energy consumption refer to yearly values calculated using the following equation:

$$\text{Specific energy consumption} = \frac{\text{energy consumption}}{\text{production}}$$

where:

- energy consumption: total amount of energy consumed by the plant, excluding the energy generated on site from by-products and effluents, expressed in MWh/year; and
- production: total annual amount of all products or throughput expressed in the appropriate units depending on the sector (e.g. kg/year, m<sup>2</sup>/year, m<sup>3</sup>/year).

#### Specific water consumption levels associated with the best available techniques (BAT-AEPLs)

The environmental performance levels related to specific water consumption refer to yearly values calculated using the following equation:

$$\text{Specific water consumption} = \frac{\text{water consumption}}{\text{production}}$$

where:

- water consumption: total amount of water consumed by the activities carried out in the plant, excluding domestic-type usage, expressed in m<sup>3</sup>/year; and
- production: total annual amount of all products or throughput expressed in the appropriate units depending on the sector (e.g. kg/year, m<sup>2</sup>/year, m<sup>3</sup>/year).

**Specific waste generation levels associated with the best available techniques (BAT-AEPLs)**

The environmental performance levels related to specific waste generation refer to yearly values calculated using the following equation:

$$\text{Specific waste generation} = \frac{\text{waste generation}}{\text{production}}$$

where:

waste generation: total amount of waste generated by the plant, expressed in kg/year; and  
production: total annual amount of all products or throughput expressed in the appropriate units depending on the sector (e.g. coated units/year, kg/year, m<sup>2</sup>/year, m<sup>3</sup>/year).

## 18.1 BAT conclusions for surface treatment using organic solvents

### 18.1.1 General BAT conclusions

#### 18.1.1.1 Environmental Management Systems

*[This BAT is based on information given in Section 18.1]*

*[Note to the TWG: the following description of the general EMS features is based on standard text agreed at the level of the IED Article 13 Forum and used in recent documents such as the BAT conclusions for CWW, IRPP, NFM, REF. In view of the recent changes to ISO 14001 and EMAS there are discussions on a new standard text. The new text will be used for the final version. The possibilities for changes are therefore limited to the section specifically for STS issues]*

**BAT 1. In order to improve the overall environmental performance, BAT is to implement and adhere to an Environmental Management System (EMS) that incorporates all of the following features:**

- i. commitment of the management, including senior management;
- ii. definition, by the management, of an environmental policy that includes the continuous improvement of the environmental performance of the installation;
- iii. planning and establishing the necessary objectives, targets and procedures, in conjunction with financial planning and investment;
- iv. implementation of procedures paying particular attention to:
  - (a) structure and responsibility;
  - (b) recruitment, training, awareness and competence at all levels;
  - (c) communication internally and externally;
  - (d) employee involvement;
  - (e) documentation;
  - (f) effective process control;
  - (g) maintenance programmes;
  - (h) emergency preparedness and response;
  - (i) safeguarding compliance with environmental legislation;
- v. checking performance and taking corrective action, paying particular attention to:
  - (a) monitoring and measurement (see also the JRC Reference Report on Monitoring of Emissions to Air and Water from IED Installations – ROM);
  - (b) corrective action;
  - (c) maintenance of records;
  - (d) independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained.
- vi. review, by senior management, of the EMS and its continuing suitability, adequacy and effectiveness;
- vii. following the development of cleaner technologies;
- viii. consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;
- ix. application of sectoral benchmarking on a regular basis.



Specifically for surface treatment using organic solvents, it is also important to consider the following features of the EMS:

- Interaction with other management systems, in particular financial planning, quality control and assurance, health and safety, maintenance and training to achieve shared objectives.
- Ongoing environmental improvement and planning to reduce the environmental footprint of an installation. In particular:
  - assessing the overall environmental performance of the plant (see BAT 12)
  - taking into account cross-media considerations especially the maintenance of a proper balance between solvent emissions reduction and consumption of energy (see BAT 20), water (see BAT 22) and raw materials.
- The inclusion of:
  - a raw material evaluation system to reduce the use of environmentally harmful substances and a plan to optimise the use of solvent in the process (see BAT 3);
  - a solvent mass balance to measure and manage emissions (see BAT 9);
  - a maintenance plan to reduce OTNOC (see BAT 13)
  - an energy efficiency plan (see BAT 20);
  - a water management plan (see BAT 22);
  - a waste management plan (see BAT 25);
  - an odour management plan (see BAT 26).

#### **Applicability**

Generally applicable. The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have, as well as by the type and quantity of materials used.

## 18.1.1.2 Storage and handling of solvents

**BAT 2.** In order to prevent or minimise pollution from unplanned releases and fugitive emissions during storage and handling of hazardous materials, and to assist the site closure process, BAT is to use an appropriate combination of the techniques given below.

Technique	Description
<b>Management techniques</b>	
a	Preparation and implementation of plans for the prevention and control of leaks and spillages
b	Inspection and maintenance to reduce solvent emissions
<b>Storage techniques in production areas</b>	
c	Sealing or covering of containers
d	Minimisation of storage of hazardous materials in production areas
e	Minimise the amount of materials stored
<b>Techniques for pumping and handling liquids</b>	
f	Automatic paint feed, colour changing and cleaning systems
g	Prevention of leaks and spillages during pumping
h	Prevention of overflows during pumping
i	Prevention of VOC vapour releases during delivery
j	Containment for spills when moving solvents

[This BAT is based on information given in Section 17.2]

**18.1.1.3 Selection of surface treatment processes****18.1.1.3.1 Material-based techniques (including substitution)**

**BAT 3.** In order to minimise the environmental impact of the materials used, BAT is to use techniques (a) and (b) and an appropriate combination of techniques (c) to (k) given below.

	<b>Technique</b>	<b>Description</b>	<b>Applicability</b>	
a	Systematic evaluation of the environmental impact of used materials	Systematic evaluation of adverse environmental impacts of materials used and identification of substances that may be replaced by others with lower environmental impacts	Generally applicable. The scope (e.g. level of detail) and nature of the evaluation will generally be related to the nature, scale and complexity of the plant and raw materials used, and the range of environmental impacts it may have	
b	Deployment of a management plan to minimise the use of solvents in the process	The management plan aims at identifying and implementing actions to minimise the use of solvents (e.g. less paint coats, number of colours, colour batching, optimise spray pulverisation)	Generally applicable	
c	Use of high-solid solvent-based paints / coatings / inks / adhesives	Paints, coatings, liquid inks, varnishes and adhesives containing a low amount of solvents and an increased solid content	The selection of the surface treatment techniques will be restricted by the activity type, the substrate type and shape, quality requirements as well as the need to ensure that the materials, application and drying/curing techniques are mutually compatible	
d	Use of water-based paints / coatings / inks / varnishes / adhesives	Paints, coatings, liquid inks, varnishes and adhesives where organic solvent is partially replaced by water		
e	Electrocoating	Paint particles are dispersed in a water-based solution and deposited on immersed substrates under the influence of an electric field (electrophoretic deposition). It is a specific type of dip coating		
f	Use of radiation-cured ink coatings / paints / varnishes / adhesives	Paints, coatings, liquid inks, varnishes and adhesives that are cured by the activation of specific chemical groups by UV or IR radiation, or fast electrons, without heat and without emission of VOCs		
g	Use of solvent-free two-component adhesives	Two-component solvent-free adhesive materials consisting of a resin and a hardener		
h	Use of hot melt adhesives	Coating with adhesives made from the hot extrusion of synthetic rubbers, hydrocarbon resins and various additives. No solvents are used		
i	Use of powder coatings	Solvent-free coating applied as a finely divided powder and cured in thermal ovens		
j	Use of pre-coated materials	Materials coated before cutting and/or shaping and/or assembling		
k	Use of laminate film coatings	Use of polymer films applied onto a coil or web in order to give aesthetic or functional properties		Only applicable to web or coil coatings

[This BAT is based on information given in Sections 17.6, & 17.7,]

**BAT 4. The use of Cr(VI) in (pre)treatment and coating activities is not BAT.**

**Applicability**

Cr(VI) may be used in the aircraft industry where it is required by type approval regulations and also any other applications authorised under REACH.

[This BAT is based on information given in Sections 17.6.1,]

**18.1.1.3.2 Application and drying/curing techniques**

**BAT 5. In order to minimise the raw material consumption and the overall environmental impact of the application processes, BAT is to use one or an appropriate combination of the techniques given below.**

	Application Techniques	Description	Applicability ( <sup>1</sup> )
a	Roller coating	Application where rollers are used to transfer or meter the liquid coating onto a moving strip	Only applicable to flat substrates
b	Doctor blade over roller	The coating is applied to the substrate through a gap between a blade and a roller. As the coating and substrate pass, the excess is scraped off. This process can be used for high-viscosity coatings and very high coat weights, such as plastisols and rubber coatings	Only applicable to roller coating
c	'Spray, squeegee and rinse' application	Sprays used for application of cleaners, pretreatments and for rinsing. Squeegees minimise solution dragout, followed by rinsing.	Only applicable to coil coating
d	No rinse (dry in place) application	Application of conversion coatings by roller coater (chemcoater) or squeegee rollers which does not require a further water rinse	
e	Curtain coating (casting)	Workpieces are passed through a laminar film of coating discharged from a header tank	Only applicable to coating of flat substrates
f	Electrocoating (e-coat)	Paint particles dispersed in a water-based solution are deposited on immersed substrates under the influence of an electric field (electrophoretic deposition).	Only applicable to the coating of steel and certain other metal substrates
g	Flooding	The workpieces are transported via conveyor systems into a closed channel, which is then flooded with the paint material via injection tubes. The excess material is collected and reused	Generally applicable for coating smaller workpieces
h	Vacuum coating	The workpieces are transported via conveyor systems into a closed chamber where a vacuum is created. The paint is applied from four different sides	Only applicable for coating of furniture and wood materials
i	Air-assisted airless spraying	An air flow (shaping air) is used to modify the spray cone of an airless spray gun	Generally applicable
j	Manual electrostatic guns	Paint is atomised by air or pressure in an electrostatic field, and is transported along the electric flux lines	Generally applicable
k	Pneumatic atomisation with inert gases	Pneumatic paint application with pressurised carbon dioxide	May not be applicable to coating of furniture and wood materials
l	Pneumatic atomisation with Nitrogen	Pressured air used in pneumatic spray guns for atomising the paint is partially replaced by nitrogen	Applied in vehicle coating

m	High-volume low-pressure (HVLP) atomisation	Atomisation of paint in a spray nozzle by mixing paint with high volumes of air with a low pressure (max. 1.7 bar). HVLP guns have a paint transfer efficiency of > 50 %.	Generally applicable
n	Electrostatically assisted high-speed rotation discs and bells	Atomisation by high-speed rotational discs and bells and shaping the spray jet with electrostatic fields	Generally applicable
o	Electrostatically assisted air or airless spraying	Shaping the spray jet of pneumatic or airless atomisation with an electrostatic field. Electrostatic paint guns have a transfer efficiency of > 60 %. Fixed electrostatic methods have a transfer efficiency of up to 75 %.	Generally applicable
p	Hot spraying	Pneumatic atomisation with hot air or heated paint	Applicable for high viscosity coatings

(<sup>1</sup>) The selection of the application processes may be restricted by the substrate type and shape and the need to ensure that the materials, application and drying/curing techniques are mutually compatible.

[This BAT is based on information given in Sections 17.7]

**BAT 6. In order to minimise solvent and other raw material consumption and reduce solvent emissions, BAT is to minimise material losses by using an appropriate combination of the techniques given below.**

	Technique	Description	Applicability
a	Centralised ink / paint / coating / solvent supply	Supply of inks, paints, coatings and solvents to the application area by direct piping with ring lines including system cleaning such as pig clearing or air flushing	Generally applicable
b	Advanced mixing systems	Computer-controlled mixing equipment to compose the desired paint / coating / ink	
c	Ink / paint / coating / solvent supply at point of application	Supply of ink / paint / coatings and solvents from small transport containers placed near the application area.	

[This BAT is based on information given in Section 17.2.4]

**BAT 7. In order to minimise the energy consumption and the overall environmental impact from drying/curing, BAT is to use an appropriate combination of the techniques given below.**

	Technique	Description	Applicability ( <sup>1</sup> )
a	Inert gas convection drying/curing	The inert gas (nitrogen) is heated in the oven, enabling solvent loading above the LEL. Solvent loads of > 1200 g/m <sup>3</sup> nitrogen are possible	Not applicable where dryers need to be opened regularly
b	Induction drying/curing	Online thermal curing or drying by electromagnetic inductors that generate heat inside the metallic workpiece by an oscillating current	Only applicable to metal substrates
c	Microwave and HF drying	Drying using microwave or high-frequency (HF) electromagnetic microwaves	Only applicable to water-based coatings and inks and non-metallic substrates
d	Radiation curing	Radiation curing is applied based on resins and reactive diluents (monomers) which react together on exposure to radiation (infrared radiation (IR), near-infrared radiation (NIR), ultraviolet (UV)), or high-energy electron beams (EB)	Only applicable with specific coatings and inks. IR and UV are line of sight technologies only.

e	Combined convection/ IR radiation drying	Drying of a wet surface with a combination of circulating hot air (convection) and an infrared radiator (also called a thermal reactor)	Generally applicable with low-solvent coatings and inks (e.g. water-based paints)
<sup>(1)</sup> The selection of the drying/curing processes may be restricted by the substrate type and shape, quality requirements and the need to ensure that the materials, application and drying/curing techniques are mutually compatible.			

[This BAT is based on information given in Sections 17.8]

#### 18.1.1.4 Cleaning

**BAT 8.** In order to minimise VOC emissions from cleaning processes, BAT is to use technique (a) and an appropriate combination of techniques (b) to (m) given below.

Technique		Description
a.	Optimisation of cleaning	Minimise the need to clean and select cleaning methods that: <ul style="list-style-type: none"> <li>are compatible with the surfaces to be cleaned and contamination type;</li> <li>reduce consumption of solvent-based cleaning agents, waste generation and emissions</li> </ul>
b.	Prevention of paint deposition on areas and equipment by covers or foils	Covering application areas and equipment (e.g. spray booth walls and robots) susceptible to overspray and drips, etc. with fabric covers or disposable foils where foils are not subject to tearing or wear
c.	Solids removal prior to full cleaning	Minimising solvent-using cleaning by solids removal in a (dry) concentrated form before solvent cleaning usually by hand, with or without the aid of small amounts of cleaning solvent.
d.	Manual cleaning with pre-impregnated wipes	Wipes pre-impregnated with cleaning agents may be used for manual cleaning. Cleaning agents may be solvent-based, low-volatility solvents or solvent-free.
e.	Using low-volatility cleaning agents	Application of low-volatility solvents as cleaning agents, usually with more powerful cleaning action, reducing or eliminating evaporation.
f.	Water-based cleaning	Cleaning systems using water-based detergent or water-miscible solvents such as alcohols or glycols
g.	Enclosed washing machines using solvents	Automatic batch solvent-based cleaning/degreasing in encapsulated washing machines with integrated solvent recovery or extraction to treatment
h.	Purging with solvent recovery	Solvent is used to purge the guns/applicators and lines between colour changes to prevent cross contamination. The purge and cleaning solvent can be collected, stored and reused.
i.	Cleaning with high pressure water spray	Automatic batch cleaning of components using water-based cleaning systems. High-pressure water spray and sodium bicarbonate systems or similar may also be used for cleaning of machine parts.
j.	Ultrasonic cleaning	Cleaning in a liquid using high-frequency vibrations to loosen the adhered contamination
k.	Dry ice (CO <sub>2</sub> ) cleaning	Cleaning of metallic or plastic surfaces by blasting with CO <sub>2</sub> chips or snow
l.	CO <sub>2</sub> Snow cleaning	Surface cleaning by use of accelerated CO <sub>2</sub> snow with an applicator (nozzle array) installed on a robot
m.	Plastic shot blast cleaning	Plastic shot blasting of panel jigs and body carriers to remove excess paint build-up

#### Applicability

Generally applicable. The selection of cleaning techniques may be restricted by the type of process, the substrate or equipment to be cleaned and the type of contamination.

[This BAT is based on information given in Section 17.9]

**18.1.1.5 Monitoring****18.1.1.5.1 Solvent mass balance**

**BAT 9.** BAT is to compile, at least on an annual basis, a solvent mass balance of the solvent inputs and outputs of the plant, as defined in Part 7(2) of Annex VII to Directive 2010/75/EU. The accuracy of the solvent mass balance data is maximised by using all of the techniques given below.

Technique		Description
a.	Implementation of solvent tracking system	A solvent tracking system aims to keep control of both the used and unused quantities of solvents returned to storage from the application zone.
b.	Full identification, characterisation and quantification of the relevant emission sources	This includes: <ul style="list-style-type: none"> <li>• identification and listing of emissions sources, i.e. WGT system, each fugitive emissions source;</li> <li>• substantiated quantification of each emission source's contribution and the methodology used: measurement, calculation using emission factors, estimation based on operational parameters, etc.</li> <li>• regular update of emissions data.</li> </ul>
c.	Monitoring of changes that influence normal operation	Any change that could influence the accuracy of the solvent mass balance is recorded, such as: <ul style="list-style-type: none"> <li>• malfunctions of the waste gas treatment: date and period of time;</li> <li>• changes that may influence air/gas flow rates, e.g. replacement of fans, drive pulleys, motors; the date and type of change are recorded, e.g. replacement to original specification, refurbished, upgraded</li> </ul>

**Applicability**

Generally applicable.

*[This BAT is based on information given in Section 17.3]*

**18.1.1.5.2 Emissions to air in waste gases**

**BAT 10.** BAT is to monitor emissions to air in waste gases with at least the frequency given below and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Parameter	Activity	Standard(s)	Minimum monitoring frequency	Monitoring associated with
Dust	Coating of vehicles	EN 13284-1	Once every year	BAT 19
	Coating of plastic workpieces and metal surfaces not described in other sections			
	Coating and printing of metal packaging			
	Coating of furniture and wood materials			
	Coating of aircraft			
	Coating and printing of metal packaging			
VOCs	Coating of plastic workpieces and metal surfaces not described in other sections	EN 12619	Once every year <sup>(1)</sup>	BAT 16
	Coil coating			
	Coating of furniture and wood material			
	Coating of aircraft			
	Coating and printing of metal packaging			
	Coating of textiles, foil and paper			
	Heatset web offset printing			
	Flexible packaging and non-publication gravure printing			
	Publication gravure printing			
	Manufacturing of adhesive tapes			
Coating of textiles, foils and paper				
DMF	Coating of textiles, foils and paper <sup>(2)</sup>	CEN/TS 13649:2014	Four times a year	
NO <sub>x</sub> <sup>(3)</sup>	Coating of plastic workpieces and metal surfaces not described in other sections	EN 14792	Once every year	BAT 18
	Coating of furniture and wood material			
	Coating and printing of metal packaging			
	Heatset web offset printing			
	Flexography and non-publication gravure printing			
	Coil coating			
Coating of textiles, foil and paper				
CO <sup>(2)</sup>	Coating of plastic workpieces and metal surfaces not described in other sections	EN 15058	Once every year	BAT 18
	Coating of furniture and wood material			
	Coating and printing of metal packaging			
	Heatset web offset printing			
	Flexible packaging and non-publication gravure printing			
	Coil coating			
	Coating of textiles, foil and paper			

<sup>(1)</sup> Continuous monitoring if the average emitted TOC load is greater than 10 kg/h.  
<sup>(2)</sup> When DMF is used.  
<sup>(3)</sup> Only related to thermal treatment techniques of waste gases.

[This BAT is based on information given in 17.3.5]



### 18.1.1.5.3 Emissions to water

**BAT 11.** BAT is to monitor emissions to water with at least the frequency given below and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Parameter	Activity	Standard(s)	Minimum monitoring frequency	Monitoring associated with
TSS	Coating of vehicles	EN 872	Once every month <sup>(2)</sup>	BAT 24
COD <sup>(1)</sup>	Coating of vehicles	No EN standard available		
Cr(VI)	Coating of aircraft	Various EN standards available (e.g. EN ISO 10304-3, EN ISO 23913)		
Cr <sub>total</sub>	Coil coating	Various EN standards available (e.g. EN ISO 11885, EN ISO 17294-2, EN ISO 15586)		
Ni	Coating of vehicles			
	Coil coating			
Zn	Coating of vehicles			
	Coil coating			

<sup>(1)</sup> TOC monitoring may be used in place of COD as it does not rely on the use of very toxic compounds.  
<sup>(2)</sup> Monitoring frequencies may be reduced if the emission levels are proven to be sufficiently stable.

*[This BAT is based on information given in 17.3.6]*

### 18.1.1.6 Overall environmental performance

**BAT 12.** In order to facilitate the improvement of the overall environmental performance of STS plants, in particular for VOC emissions and energy consumption, BAT is to:

- identify the process areas / sections / steps that have the greatest contribution to the emissions and consumption and the greatest potential for improvement:
  - identify corrective/improvement actions to minimise emissions and consumption;
  - regular (e.g. on a monthly or annual basis) update of the collected data;
  - disseminate best practices within the group and/or industry sector.

#### Applicability

Generally applicable.

*[This BAT is based on information given in Section 17.1.3]*

### 18.1.1.7 Inspection and maintenance to reduce solvent emissions during OTNOC

**BAT 13.** In order to prevent or minimise pollution from OTNOC, BAT is to implement an inspection and maintenance plan to reduce the occurrence, duration and impact of OTNOC periods.

#### Description

Planned and regular inspection and maintenance directly minimise VOC emissions, in particular by reducing breakdowns and OTNOC, including fugitive leaks of solvent as vapours and liquids.

The maintenance plan for the off-gas extraction and treatment equipment includes regular inspection, preventive and corrective actions to ensure that the off-gas extraction and treatment equipment operates according to its specifications and with optimal efficiency and minimises the occurrence, duration and impact of OTNOC. Defects in WGT can give rise to VOC emissions of up to 0.4 % of the annual VOC inputs per day of OTNOC.

[This BAT is based on information given in Section 17.2.7]

### 18.1.1.8 Waste gas extraction and treatment

#### 18.1.1.8.1 Enclosure, extraction and treatment

**BAT 14.** In order to minimise fugitive and total emissions of VOCs and dust from the production and storage areas, BAT is to use technique (a) and an appropriate combination of techniques (b) to (i).

Technique	Description	Applicability
a	System selection, design and optimisation	Generally applicable
b	Air extraction and treatment at the point of application	May not be applicable to existing units due to technical and space limitations
c	Air extraction and treatment from the production hall	May not be applicable to existing lines due to technical limitations and energy consumption considerations
d	Enclosure of the paint / coating / ink preparation room	May not be applicable to existing lines due to technical limitations
e	Air extraction and treatment from the drying/curing processes	Generally applicable
f	Use of air seals on the entrance and the exit of the ovens/dryers	Generally applicable
g	Negative pressure in drying	May not be applicable to existing lines due to technical limitations
h	Air extraction and treatment from the cooling zone	May not be applicable to existing lines due to technical limitations and energy consumption considerations
i	Air extraction and treatment from storage of raw materials and wastes	May not be applicable to existing lines due to technical limitations and energy consumption considerations
j	Air extraction from cleaning areas	May not be applicable to existing lines due to technical limitations and energy consumption considerations

[This BAT is based on information given in Section 17.10.1 and 17.10.2]

#### 18.1.1.8.2 VOC emissions to air in waste gases

**BAT 15.** In order to minimise VOC emissions to air while limiting raw material and energy consumption, BAT is to follow as far as possible the order of priority below, using an appropriate combination of techniques given in the BAT indicated:

- minimise VOC content in off-gases (see BAT 3, BAT 5 and BAT 6);
- minimise energy consumption for off-gas extraction and treatment (see BAT 17);
- recover solvents in off-gases (see BAT 16);
- abate VOC emissions in off-gases while recovering the heat generated (see BAT 16);
- where heat recovery is not feasible, abate VOC emissions without recovery of generated heat (see BAT 16).

[This BAT is based on information given in Sections 17.1.3 & 17.10.1.1]

**BAT 16.** In order to minimise VOC emissions to air, BAT is to use one or an appropriate combination of the techniques given below.

Technique	Description	Applicability
<b>Techniques for the capture of solvents in off-gases</b> [These BAT are based on information given in Section 18.11]		
a. Condensation	Off-gas with a high VOC concentration is cooled to the point of condensing the VOCs. The volatility of the VOCs determines the type of cooling required	May not be applicable to low-VOC concentration off-gas streams
b. Cryogenic solvent recovery	Cooling (usually by using liquid nitrogen) the off-gas to temperatures below the dew point so that the solvent vapour condenses on a cooling surface and can be removed in liquid form. The lower the temperature the smaller the remaining load in the gas flow	May not be applicable to low-VOC concentration off-gas streams
c. Adsorption using activated carbon or zeolites	VOCs are adsorbed on the surface of activated carbon or zeolites. Also commonly applied as a concentration step to increase subsequent oxidation efficiency. Both the solvents and the adsorption media (activated carbon or other adsorbent) are recovered	Generally applicable to waste gases with solvent concentrations of $> 0.8 \text{ g/m}^3$
d. Wet scrubbing	Wet scrubbing is a mass transfer between a soluble gas or dust and a solvent – often water – in contact with each other. (For dust removal, see BAT 19).	Generally applicable. Water-based scrubbing is applicable to polar VOCs
e. Absorption using liquid	A variant of wet scrubbing. Recovery of solvents by absorption to a solvent	Generally applicable in new plants and for upgrading of existing plants
<b>II. Thermal treatment of solvents in off-gases</b> [These BAT are based on information given in Section 18.11.5]		
f. Fuel supplement in process heating	The off-gas is sent to an existing heater (e.g. boiler) as combustion air and complementary fuel	Generally applicable

g.	Thermal oxidation	Oxidation of VOCs in a simple oxidation chamber by chemical reaction with oxygen without heat recovery	Especially suitable for high VOC concentrations (5–16 g/Nm <sup>3</sup> ) and for batch processes with all types of solvents (and their mixtures)
h.	Recuperative thermal oxidation	Similar to thermal oxidation but with a heat exchanger that preheats the incoming off-gases with the heat of the waste gases	The technique is suitable for small to medium flow rates of < 25 000 Nm <sup>3</sup> /h for continuous processes and solvent concentration of 6–12 g/m <sup>3</sup>
i.	Regenerative thermal oxidation (2-, 3- or 5-bed)	An oxidiser with multiple beds filled with ceramic packing. The beds are heat exchangers, alternately heated by flue-waste gases from oxidation, then the flow reversed to heat the inlet air to the oxidiser. The flow is reversed on a regular basis	Commonly applied to an airflow in the range of > 1 500–70 000 Nm <sup>3</sup> /h for one dual bed unit. For flows > 70 000 Nm <sup>3</sup> /h, multi-bed systems are more economic
j.	Catalytic oxidation	Oxidation of VOCs assisted by a catalyst to reduce the oxidation temperature and reduce the fuel consumption. Exhaust heat can be recovered with recuperative or regenerative types of heat exchangers. Higher oxidation temperatures (500–750 °C) are used for the treatment of off-gas from the manufacturing of winding wire	Generally applicable
<b>Other techniques for treatment of solvents in off-gases</b> [These BAT are based on information given in Section 18.11.7 & 12.4.2]			
k.	Biological waste gas treatment	Degradation of organic substances in off-gases by biological processes in a biofilter or bioscrubber	Only applicable for diluted biodegradable continuous streams WG streams or with supplementary nutrient feeding

[This BAT is based on information given in Sections 17.10.5 -17.10.7 ]

**BAT 17. In order to reduce energy consumption while abating VOC emissions to air, BAT is to use techniques (a) and (b) and an appropriate combination of techniques (c) to (h) given below.**

Technique		Description	Applicability
a.	System selection, design and optimisation	The correct system selection, design and optimisation of the off-gas extraction system and of the abatement system is necessary to achieve significant reductions in energy consumption and VOC emissions. See BAT 14	Generally applicable
b.	Off-gas pretreatment	Various techniques to remove impurities from the off-gas that affect the treatment, e.g. sticky particles, catalyst poisons (see BAT 19)	Generally applicable
c.	Utilising WGT over-capacity to reduce untreated VOC emissions	Often referred to as peak/trough smoothing. Periodic diversion of air with a low VOC concentration (e.g. from the production hall extraction) to the WGT when the WGT has over-capacity	Only applicable to thermal treatment of off-gases in batch processes with centralised WGT, such as printing
d.	Maintaining VOC concentration to WGT by using variable frequency drives	Use of a variable frequency drive fan with centralised off-gas treatment systems to modulate the airflow to match the exhaust from the equipment that may be in operation	Only applicable to central thermal WGT in batch processes such as printing
e.	Internal concentration of solvents	Off-gas is recirculated within the process (internally) in the dryers and/or in spray booths, so the VOC concentration in the off-gas increases and increases the abatement efficiency of the WGT	Applicability may be limited by health and safety factors such as the LEL
f.	External concentration of solvents	The concentration of solvent in off-gas can be increased by a continuous circular flow of the spray booth or dryer off-gas through adsorption equipment. This equipment can include: <ul style="list-style-type: none"> <li>• fixed bed adsorber with activated carbon or zeolite polymers;</li> <li>• fluidised bed adsorber with activated carbon;</li> <li>• rotor adsorber (concentrator wheel) with activated carbon</li> </ul>	This is not applicable where concentrations are high enough for autothermic incineration
g.	Plenum technique to reduce waste gas volume	Off-gases from dryers are sent to a large chamber (plenum), and partly recirculated as inlet air in the dryers. The surplus air from the plenum is sent to WGT. This cycle increases the VOC content of the dryers' air and decreases the waste gas volume	Only applicable when low solvent concentrations in dryer off-gas occur and internal recirculation of dryer air is not possible

*[This BAT is based on information given in Sections 17.10.1, 17.10.3, 17.10.4 ]*

18.1.1.8.3 NO<sub>x</sub> and CO emissions

**BAT 18.** In order to prevent or reduce NO<sub>x</sub> emissions to air while limiting CO emissions from the thermal treatment of off-gases, BAT is to apply one or both of the techniques given below.

Technique		Description
a.	Optimisation of thermal treatment conditions	Good design of the combustion chambers, burners and associated devices is combined with optimisation of combustion conditions with or without use of automatic systems and the regular planned maintenance of the combustion system according to suppliers' recommendations
b.	Use of low-NO <sub>x</sub> burners	The peak flame temperature in the combustion chamber is reduced, delaying but completing the combustion and increasing the heat transfer (increased emissivity of the flame). It is combined with increased residence time in order to achieve the desired VOC destruction

**Applicability**

The applicability may be restricted by design and/or operational constraints at existing units

[This BAT is based on information given in Section 17.10.8]

**Table 18.1: BAT-associated emission levels (BAT-AELs) for NO<sub>x</sub> emissions to air from the thermal treatment of off-gases**

Parameter	Process	Unit	BAT-AEL <sup>(1)</sup>
NO <sub>x</sub>	Thermal treatment of off-gases	mg/Nm <sup>3</sup>	< 20–150
<sup>(1)</sup> This BAT-AEL does not apply in the case that off-gases are used as fuel supplement in process heating			

The associated monitoring is given in BAT 10.

As an indication, the CO emission levels associated with the above techniques will generally be as indicated in Table 18.2.

**Table 18.2: Indicative levels for CO emissions to air from the thermal treatment of off-gases**

Parameter	Process	Unit	Indicative emission level <sup>(1)</sup>
CO	Thermal treatment of off-gases	mg/Nm <sup>3</sup>	< 20–200
<sup>(1)</sup> This indicative level does not apply in the case that off-gases are used as fuel supplement in process heating			

The associated monitoring is given in BAT 10.

## 18.1.1.8.4 Dust emissions

**BAT 19.** In order to reduce dust emissions to air from substrate surface preparation, cutting, coating application and finishing processes, BAT is to use one or a combination of the techniques given below.

Technique		Description	Applicability
a.	Wet separation spray booth (flushed impact panel)	A water curtain cascading vertically down the spray cabin rear panel captures paint particles from over-spray. The water-paint mixture is captured in a reservoir and the water recirculated	Generally applicable. There may be technical and economic restrictions for retrofitting existing plants
b.	Wet scrubbing	See BAT 16 Paint particles and other dust in the off-gas are separated in scrubber systems by intensive mixing of waste air with water	Generally applicable to both water-based and solvent-based paints
c.	Venturi scrubbing	Separation of paint particles (overspray) from paint booth exhaust air using a venturi system with circulating water	Generally applicable in high throughput paint shops, such as vehicle coating
d.	Dry overspray separation with pre-coated material	A dry paint overspray separation process using membrane filters combined with limestone as pre-coating material to prevent fouling of the membranes	Generally applicable in new or existing installations, with water-based or solvent-based paints
e.	Dry overspray separation using cardboard box (labyrinth) filters	Mechanical dry separation system using cardboard box modules in a labyrinthine flow path	Applicable coating of metal and plastics parts and at lower throughput vehicle paint shops
f.	Electrostatic filter (precipitator)	In electrostatic precipitators, particles are charged and separated under the influence of an electrical field. In a dry ESP, the collected material is mechanically removed (e.g. by shaking, vibration, compressed air). In a wet ESP (e.g. e-scrubber), it is flushed with a suitable liquid, usually water	Generally applicable in a wide range of operating conditions

[This BAT is based on information given in Section 17.10.4.]

**Table 18.3: BAT-associated emission levels (BAT-AELs) for dust emissions to air from substrate surface preparation, cutting, coating application and finishing processes**

Parameter	Activity	Process/product type	Unit	BAT-AEL
Dust	Coating of vehicles	Spray booth emissions / all product types	mg/Nm <sup>3</sup>	< 0.3–3
	Coating of aircraft	Preparation (e.g. sanding, blasting) and coating		
	Coating of plastic workpieces, and metal surfaces not described in other sections	Spray booth emissions / all product types		
	Coating and printing of metal packaging	Application, drying, cutting / all product types		

The associated monitoring is given in BAT 10.

### 18.1.1.9 Energy management and energy efficiency

**BAT 20.** In order to facilitate the reduction of the energy consumption of surface treatment with organic solvents, BAT is to use both of the techniques given below.

	Technique	Description
a.	Energy efficiency plan	An energy efficiency plan entails defining and calculating the specific energy consumption of the activity, setting key performance indicators on an annual basis (e.g. MWh/tonne of product) and planning the periodic improvement targets and related actions
b.	Energy balance record	An energy balance record provides a breakdown of the energy consumption and generation (including exportation) by the type of source (e.g. electricity, gas, conventional liquid fuels). This includes: (i) defining the energy boundary of the activity; (ii) information on energy consumption in terms of delivered energy; (iii) information on energy exported from the plant; (iv) energy flow information (e.g. Sankey diagrams or energy balances) showing how the energy is used throughout the process. The energy balance record is adapted to the specificities of the plant in terms of process(es) carried out, materials, etc

#### Applicability

The scope (e.g. level of detail) and nature of the energy efficiency plan will generally be related to the nature, scale and complexity of the installation and energy types used.

*[This BAT is based on information given in Section 17.5]*

**BAT 21.** In order to increase energy efficiency, BAT is to use an appropriate combination of the techniques given below.

	Technique	Description	Applicability
a.	System selection, design and optimisation of the waste gas extraction and abatement processes	The correct system selection, design and optimisation of the waste gas extraction system and of the abatement system has a large impact on energy consumption and VOC emissions See BAT 14 and BAT 17.	Generally applicable
b.	Thermal insulation of tanks and vats containing heated liquids, combustion and steam systems	This may be achieved by: <ul style="list-style-type: none"> <li>• using double skinned tanks;</li> <li>• using pre-insulated tanks;</li> <li>• applying insulation to combustion equipment, steam and hot water pipes.</li> </ul>	
c.	CCHP (combined cooling, heat and power)	A cogeneration system with an absorption chiller that uses low-grade heat to produce chilled water. Also called trigeneration	
d.	Recovery of heat from off-gases	Energy recovery from off-gas thermal treatment processes and hot air streams (e.g. from dryers, cooling zones)	
e.	Oxidiser heat saving during shutdown periods	Oxidiser heat is kept inside chambers during production shutdown periods (e.g. weekends)	
f.	Flow adjustment of process air and off-gases	Adjust the flow of process air and off-gases according to the need. Reduce air ventilation during idle operation or maintenance	



g.	Spray booth off-gas recirculation	Capture and recirculate off-gas from the spray booth in combination with efficient paint overspray separation. Energy consumption is less than in the case of fresh air use	Only applicable to spray coating sectors
h.	Temperature and humidity optimisation of the process air	Maintain process air conditions (humidity, temperature) at the desired ranges	Generally applicable
i.	Optimisation of energy consumption for the warm air circulation required for curing,	Air is blown into a single part of the booth and distributed using an air turbulator which turns the laminar air flow into the desired turbulent flow. In general, ventilation uses slightly less energy.	Only applicable to spray coating sectors

[This BAT is based on information given in Section 17.10.1.1 and 17.5]

**Table 18.4: BAT-associated energy efficiency levels (BAT-AEELs) for specific energy consumption of the plant**

Activity	Product type	Unit	BAT-AEEL
Coating of vehicles	Passenger cars	MWh/unit coated	0.5–1
	Vans		0.8–2
	Truck cabins		1–2
	Truck chassis		0.3–0.5
Coil coating	All product types	kWh/t of coated coil	100–600
Manufacturing of winding wires	Average diameter > 0.1 mm	kWh/kg of coated wire	< 5
Coating and printing of metal packaging	All product types	kWh/m <sup>2</sup> of coated surface	0.2–2
Heatset web offset printing	All product types	kWh/kg of ink consumed	8–25
Flexible packaging and non-publication gravure printing	All product types	kWh/m <sup>2</sup> of printed area	0.05–0.35
Publication gravure printing	All product types	kWh/kg of printed substrate (all coated sides)	0.4–0.75
Coating of textiles, foils and paper	PU and PVC coating of textile	kWh/m <sup>2</sup> of coated surface	1–25

#### 18.1.1.10 Water use and waste water generation

**BAT 22.** In order to optimise water consumption and reduce waste water generation, BAT is to apply a water management plan and water audits.

##### Description

A water management plan includes:

- flow diagrams and a water mass balance;
- establishment of water efficiency objectives;
- implementation of water optimisation techniques (e.g. control of water usage, recycling, detection and repair of leaks).

Water audits are carried out at least annually to increase the reliability of controls and to ensure the objectives of the water management plan are met.

**Applicability**

Only applicable to plants using water-based cleaning, pretreatments, or emission control techniques such as wet scrubbers (including absorption in water). The scope (e.g. level of detail) and nature of the water management plan will generally be related to the nature, scale and complexity of the installation.

[This BAT is based on information given in Section 17.4]

**BAT 23. In order to reduce water consumption and waste water discharges from degreasing/cleaning processes and from wet scrubber systems capturing paint overspray, BAT is to apply an appropriate combination of the techniques given below.**

Technique	Description	Applicability	
a	Optimisation of water usage	Water usage and discharge are optimised by managing the flow and water quality, e.g. of rinse and process waters. This may also assist the reuse and recycling of water	Applicable where water-based techniques are used, e.g. cleaning, treatment baths, coatings and/or wet scrubber are used
b	Reverse cascade rinsing	Multiple stage rinsing in which the water flows in the opposite direction to the workpieces/substrate. It allows a high rinsing rate with a low water consumption	Applicable where water-based techniques are used, e.g. cleaning and/or treatment baths, and /or coatings
c	Reuse/recycling of water	Spent rinse water can be regenerated using such techniques such as ion exchange or filtration. Closed loop systems can be used in systems such as such as in cooling towers or heat exchangers	Generally applicable
d	Recycling of wet/venturi scrubber effluent	Effluent from venturi scrubbers is treated on a continuous basis. Paint particles are coagulated and flocculated and the resulting paint sludge is removed continuously, allowing the water to be recycled	Applicable to wet/venturi scrubber overspray systems for paint overspray capture
e	Regeneration by ion exchange	Ion exchange is the removal of undesired or hazardous ionic constituents of waste water and their replacement by ions $H^+$ and $OH^-$ from an ion exchange resin	Applicable to ionic contaminants in water streams
f	Magnetic separator	Magnetic material is extracted from water using a magnetic force	Applicable to magnetic particles
g	Membrane filtration	Removal of contaminants from water by filtration through membranes. These may be micro-, ultra- or nano- pore size	Generally applicable

[This BAT is based on information given in Section 17.4]

**Table 18.5: BAT-associated environmental performance levels for total water consumption for the following activities**

Activity	Product type	Unit	BAT-AEPL
Coating of vehicles	Passenger cars	$m^3/unit^*$ coated	0.7–1.5
	Vans		1–2.5
	Truck cabins		0.7–3
	Truck chassis		< 1–5
Coil coating	All types	$m^3/t$ of coated coil	0.1–2.4
Coating and printing of metal packaging	Coating of 2-piece cans	1/1000 cans	90–110

\* Unit here refers to 'vehicle produced'.

## 18.1.1.11 Emissions to water

**BAT 24.** In order to reduce emissions to water from water-based processes BAT is to apply an appropriate combination of the techniques given below.

Techniques		Description	Applicability
a.	Replacement of Cr(VI) passivation	Replacement of Cr(VI) by Cr(III) conversion coating or an alternative system, e.g. thin organic coatings	Applicable only to Cr(VI) conversion coatings
<b>Process-integrated techniques</b>			
b.	Use of 'no-rinse' or 'dry in place' application	Roller or squeegee application of pretreatment products to coil surface. The wet film is dried in place without rinsing and painted immediately	Only applicable in coil coating
c.	Reverse cascade rinsing	See BAT 23	
<b>Waste water treatment techniques</b>			
d.	Reduction of Cr(VI)	Conversion of Cr(VI) by a chemical reducing agent to Cr(III) to enable precipitation and removal	Applicable only to Cr(VI) from conversion coatings or soluble pigments
e.	Coagulation and flocculation	Coagulation and flocculation are used to separate suspended solids from waste water and are often carried out in successive steps. Coagulation is carried out by adding coagulants with charges opposite to those of the suspended solids. Flocculation is a gentle mixing stage so that collisions of microfloc particles cause them to bond to produce larger flocs. It may be assisted by adding polymers..	Generally applicable
f.	pH adjustment and neutralisation	The adjustment of the pH of waste water by the addition of chemicals. The pH may be adjusted to a specific level for the precipitation of metals (e.g. zinc) or close to neutral (approximately 7) for discharge.	
g.	Separation	The separation of suspended particles by gravitational settling (sedimentation), flotation or filtration.	
h.	Filtration	The separation of solids from waste water by passing them through a porous medium, e.g. sand filtration, nano-, micro-filtration and ultra-filtration.	

[This BAT is based on information given in Sections 17.6.1, 17.3.3, 17.7.3.4 and 17.11]

**Table 18.6: BAT-associated emission levels (BAT-AELs) for direct discharges to a receiving water body**

Parameter	Activity	BAT-AEL (daily average)
Total suspended solids (TSS)	Vehicle coating	5–30 mg/l
Chemical oxygen demand (COD)	Vehicle coating	30–200 mg/l
Total chromium (expressed as Cr)	Coil coating	0.01-0.15mg/l
	Aircraft	
Nickel (expressed as Ni)	Vehicle coating	< 0.05–0.2 mg/l
	Coil coating	
Zinc (expressed as Zn)	Vehicle coating	< 0.02–0.25 mg/l
	Coil coating	
Hexavalent chromium Cr(VI) during phase-out or where registrations exist under REACH for its use	Coil coating	0.005-0.025 mg/l
	Aircraft	

The associated monitoring is given in BAT 11.

**18.1.1.12 Waste minimisation**

**BAT 25.** In order to prevent or, where that is not practicable, to reduce waste generation, BAT is to implement a waste management plan that incorporates all of the techniques given below.

Technique		Description
a	Monitor waste quantities	Annual recording of waste quantities produced by type. Determination of solvent content periodically (at least annually) by using analysis or calculation. Solvent contained in collected waste is one of the parameters of the solvent mass balance (see BAT 9)
b	Minimise the solvent content of wastes	Techniques to minimise the solvent content of waste include: <ul style="list-style-type: none"> <li>recovery of solvents by filtration or distillation (see BAT 8);</li> <li>removal of the solvent content of wipes by gravitational draining, a wringer or a centrifuge</li> </ul>
c	Minimise the total quantity of wastes	Techniques to minimise the quantity of waste produced include: <ul style="list-style-type: none"> <li>reduction of the water content of the waste, e.g. by using a filter press for the sludge treatment);</li> <li>reduction of the sludge and waste solvent generated, e.g. by reducing the number of cleaning cycles (see BAT 3);</li> <li>use of reusable containers, reuse of the containers for other purposes, or recycling of the container material</li> </ul>

**Applicability**

Generally applicable.

*[This BAT is based on information given in Section 17.12]*

**18.1.1.13 Odour emissions**

**BAT 26.** In order to prevent or, where that is not practicable, to reduce odour emissions, BAT is to set up, implement and regularly review an odour management plan, as part of the environmental management system (see BAT 1), that includes all of the following elements:

- a protocol containing actions and timelines;
- a protocol for response to identified odour incidents, e.g. complaints;
- an odour prevention and reduction programme designed to identify the source(s), to characterise the contributions of the sources, and to implement prevention and/or reduction measures.

**Applicability**

The applicability is applicable to cases where an odour nuisance at sensitive receptors is expected and/or has been substantiated.

*[This BAT is based on information given in Section 17.13]*

## 18.1.2 BAT conclusions for the coating of vehicles

The BAT conclusions in this section apply to the coating of vehicles (passenger cars, vans, truck cabins and truck chassis), and apply in addition to the relevant general BAT conclusions given in Section 18.1.1.

### 18.1.2.1 VOC emissions, energy and raw material consumption

**BAT 27.** In order to minimise the consumption of solvents, other raw materials and energy, as well as to reduce VOC emissions, BAT is to select one of the coating systems given below.

*[This BAT is based on information given in Sections 2.4.2]*

Coating system	Description	Applicability
a. Mixed (SB-mix) system	A coating system where one coating layer (primer or base coat) is water-based	Applicable to major upgrades
b. Water-based (WB) system	Coating system where the primer and base coat layers are water-based	Applicable to new plants/units. May not be applicable to existing plants/units due to space limitations
c. Integrated process system	A coating system that reduces energy consumption by: <ul style="list-style-type: none"> <li>• reducing drying and curing by using either: <ul style="list-style-type: none"> <li>○ a base coat type which combines the functions of primer and base coat, or</li> <li>○ wet-in-wet-in-wet processes (3-wet)</li> </ul> </li> <li>• dry separation of overspray in combination with spray booth air recirculation</li> </ul>	

**BAT 28.** In order to minimise solvent and other raw material consumption and reduce solvent emissions, BAT is to use:

- robot application of sealants and coatings to internal and external surfaces;
- automated colour changing and line purging with solvent capturing (see also BAT 6).

#### Applicability

May not be applicable to low throughput production.

*[This BAT is based on information given in Sections 2.4.6 & 17.2.5]*

**Table 18.7: BAT-associated emission levels (BAT-AELs) for total emissions of volatile organic compounds from the coating of vehicles**

Parameter	Vehicle type	Type of plant	Unit	BAT-AEL <sup>(1)</sup>
Total emissions of volatile organic compounds as calculated by the solvent mass balance	Passenger cars	Existing	g/m <sup>2</sup> <sup>(2)</sup>	8–30
		New		8–20
	Vans	Existing		10–35
		New		10–25
	Truck chassis	Existing		15–60
		New		15–50
	Truck cabins	Existing		8–50
		New		8–40
	Buses	New and existing		90-150

<sup>(1)</sup> The BAT-associated emission levels refer to the sum of all processes from electrophoretic coating or any other kind of coating processes through to the final wax and polish of top coating, including the cleaning of production equipment, both during and outside of production time.

<sup>(2)</sup> The surface area is defined according to Directive 2010/75/EU, Annex VII, Part 3.2.

The associated monitoring is given in BAT 9.

### 18.1.2.2 Waste generation

**Table 18.8: BAT-associated environmental performance levels (BAT-AEPLs) for total waste generation from the coating of vehicles**

Parameter	Vehicle type	Unit	BAT-AEPL
Waste generation	Passenger cars	kg/unit* coated	4–8
	Vans		8–14
	Truck cabins		2–11

\* Unit refers to 'vehicle produced'.

The associated monitoring is given in BAT 25.

### 18.1.3 BAT conclusions for the coating of plastic workpieces and metal surfaces not described in other sections

*[This section addresses the following activities that were considered separately in the first STS BREF: coating of other metal surfaces, plastic workpieces, agricultural and construction equipment (ACE) and trains]*

The emission levels given below for coating of plastic workpieces and metal surfaces not described in other sections, are associated with the relevant general BAT conclusions described in Section 18.1.1.

**Table 18.9: BAT-associated emission levels (BAT-AELs) for total VOC emissions**

Parameter	Unit	BAT-AEL
Total VOC emissions as calculated by the solvent mass balance	Percentage (%) of the total solvent input	< 1–12

The associated monitoring is given in BAT 9.

**Table 18.10: BAT-associated emission levels (BAT-AELs) for fugitive VOC emissions**

Parameter	Unit	BAT-AEL
Fugitive VOC emissions as calculated by the solvent mass balance	Percentage (%) of the total solvent input	< 1–10

The associated monitoring is given in BAT 9.

**Table 18.11: BAT-associated emission levels (BAT-AELs) for VOC emissions to air in waste gases**

Parameter	Unit	BAT-AEL
VOC	mg/Nm <sup>3</sup>	< 1–35

The associated monitoring is given in BAT 10.

### 18.1.4 BAT conclusions for the coating of ships and yachts

The BAT conclusions in this section apply to the coating of ships and yachts, and apply in addition to the relevant general BAT conclusions given in Section 18.1.1.

**BAT 29.** In order to reduce VOC and dust emissions, to reduce water pollution and to improve the overall environmental performance of coating of ships and yachts, BAT is to use technique (a) in combination with an appropriate selection of techniques (b) to (v) given below.

Technique	Description	Applicability
<i>Management techniques</i>		
a.	Management systems -Dock discipline - The set of procedures, functions and task definitions, and working methods, for the prevention or limitation of emissions such as: dust emissions to air, emissions to water, and quantity of waste produced.	Generally applicable
<i>Waste and waste water management</i>		
b.	Segregation of waste and waste water streams Docks and slipways are constructed with: <ul style="list-style-type: none"> <li>• a system to collect and handle dry waste effectively and keep it separate from wet waste;</li> <li>• a system to separate waste water from storm water and run-off water.</li> </ul>	Only applicable to new docks and slipways or major upgrades of existing ones
c.	Waste water treatment Use of appropriate waste water treatment (WWT) systems that are able to effectively remove various pollutants from waste water, e.g. oil, grease, paint residues potentially containing heavy metals and biocides	Generally applicable
d.	Waste management and minimisation As part of the dock discipline manage waste by: <ul style="list-style-type: none"> <li>a minimising; recovering, reusing and recycling (particularly dry blasting material);</li> <li>b storing wastes safely in designated, labelled containers in covered areas</li> </ul>	Generally applicable
<i>Techniques relating to preparation and coating processes</i>		
e.	Partial enclosure of treatment areas Fine nets and water spray curtains can be used around areas where blasting and/or airless spray painting are carried out. To prevent dust emissions. They may be permanent or temporary.	Applicability may be restricted by the shape and size of the area to be enclosed.
f.	Full enclosure of treatment areas Blasting and/or airless spray painting may be carried out in halls, closed workshops, areas tented with architectural textiles or areas fully enclosed with nets to prevent dust emissions. Extraction and treatment of air may be possible	Applicability may be restricted by the shape and size of the area to be enclosed and quality requirements
g.	Restrictions for adverse weather condition The restriction of blasting and/or airless spray painting when adverse weather conditions are observed	Generally applicable where no full containment is in place



h.	Dry blasting – closed system, vacuum or shroud blasting	Dry blasting in closed blasting systems, such as with a suction head and centrifugal blasting using steel grit or shot in closed loop systems with low emissions	Generally applicable
i.	Wet blasting	Blasting with water containing a fine abrasive material, such as a fine cinder (e.g. copper slag cinder) or silica	Generally applicable. There may be limitations in enclosed areas
j.	(Ultra-) High-Pressure ((U)HP) water jetting or blasting	(U)HP blasting is a dustless surface treatment method using extremely high-pressure water. There are options with or without an abrasive	Generally applicable. UHP blasting may not be applicable in cold climatic conditions and on new surfaces
k.	Induction coating stripping	Moving an inductor head over the surface, causing localised fast heating of the steel to lift old coatings	Applicable where coatings are on steel > 5 mm thick
l.	Hot spraying	Solvent-free 2-component coatings are applied by using hot airless spraying. Layers of 300–1 000 microns are achieved	Applicability may be restricted by contract quality specifications
m.	Underwater hull and propeller cleaning system	Underwater cleaning system using water pressure and rotating polypropylene brushes	Not applicable for ships in full dry dock
n.	Waste reduction by using larger coating containers	Instead of traditional of 20-litre cans, paints can be delivered from paint manufacturers in larger containers to reduce hazardous waste	Generally applicable
<b><i>Techniques relating to materials and coating substitution /alternatives</i></b>			
o.	Anti-fouling release coatings based on silicones	Silicone paints have a low surface tension (non-stick) with the effect that the fouling organism cannot establish a firm attachment to the coating surface	Applicability may be restricted by contract quality specifications
p.	Hard, smooth coating with frequent mechanical fouling removal	Anti-fouling coatings may be replaced by the use of hard, resistant coating materials reducing fouling adhesion and brushing and scraping off fouling at short intervals	
q.	Electrochemical processes for anti-fouling	Anti-fouling coatings may be replaced by applying a voltage potential at the vessel surface. This causes electrolysis. Fouling is inhibited by toxic chlorine compounds produced at the surface (in salt water) and/or the pH value at the surface is shifted which inhibits the settling of fouling. This technique abates corrosion	Only applicable to metal hulled vessels. Applicability may be restricted by contract quality specifications
r.	Additional corrosion protection – cathodic protection	The immersed surface of ships can be protected against corrosion by applying cathodic protection, reducing paint layers and maintenance. It is also used to protect the surfaces of tanks within ships	

[This BAT is based on information given in Section 4.4]

### 18.1.5 BAT conclusions for coil coating

The emission levels for coil coating given below are associated with the relevant general BAT conclusions described in Section 18.1.1.

**Table 18.12: BAT-associated emission levels (BAT-AELs) for fugitive VOC emissions from coil coating**

Parameter	Unit	BAT-AEL
Fugitive VOC emissions as calculated by the solvent mass balance	Percentage (%) of the total solvent input	< 1-3

The associated monitoring is given in BAT 9.

**Table 18.13: BAT-associated emission levels (BAT-AELs) for VOC emissions to air in waste gases from coil coating**

Parameter	Type of monitoring	Unit	BAT-AEL
VOC	Continuous	mg C/Nm <sup>3</sup>	< 1-15
	Periodic		< 1-30

The associated monitoring is given in BAT 10.

### 18.1.6 BAT conclusions for the manufacturing of adhesive tapes

The emission levels for the manufacturing of adhesive tapes given below are associated with the relevant general BAT conclusions described in Section 18.1.1.

**Table 18.14: BAT-associated emission levels (BAT-AELs) for total VOC emissions from the manufacturing of adhesive tapes**

Parameter	Unit	BAT-AEL
Total VOC emissions as calculated by the solvent mass balance	Percentage (%) of the total solvent input	< 1-3

The associated monitoring is given in BAT 9.

### 18.1.7 BAT conclusions for the coating of textiles, foils and paper

The emission levels for the coating of textiles, foils and paper given below are associated with the relevant general BAT conclusions described in Section 18.1.1.

**Table 18.15: BAT-associated emission levels (BAT-AELs) for total VOC emissions from the coating of textiles, foils and paper**

Parameter	Unit	BAT-AEL
Total VOC emissions as calculated by the solvent mass balance	Percentage (%) of the total solvent input	< 1-6

The associated monitoring is given in BAT 9.

**Table 18.16: BAT-associated emission levels (BAT-AELs) for fugitive VOC emissions from the coating of textiles, foils and paper**

Parameter	Unit	BAT-AEL
Fugitive VOC emissions as calculated by the solvent mass balance	Percentage (%) of the total solvent input	< 1-5

The associated monitoring is given in BAT 9.

**Table 18.17: BAT-associated emission levels (BAT-AELs) for VOC emissions to air in waste gases from the coating of textiles, foils and paper**

Parameter	Unit	BAT-AEL
VOCs	mg C/Nm <sup>3</sup>	< 1-30

The associated monitoring is given in BAT 10.

### 18.1.8 BAT conclusions for the manufacturing of winding wire

The BAT conclusions in this section apply to the manufacturing of winding wire, and apply in addition to the relevant general BAT conclusions given in Section 18.1.1.

#### 18.1.8.1 VOC emissions and energy consumption

**BAT 30.** In order to reduce total VOC emissions and energy consumption from the manufacturing of winding wires, BAT is to use technique (a) and an appropriate combination of techniques (b) to (d) given below.

Technique		Description	Applicability
a.	Integrated drying, curing and VOC oxidation	The liquid enamel layers on the metal wire need to be cured, up to 30 times, until the desired layer thickness is obtained. The air/solvent mix resulting from the solvent evaporation process is treated in a catalytic oxidiser. The process heat from the catalytic oxidiser is used in the drying process to heat up the circulating airflow and/or as process heat for other purposes within the installation	Generally applicable
b.	Solvent-free lubricants	Solvent-free lubricants can be applied with two systems: <ul style="list-style-type: none"> <li>the wire is drawn through a lubricant-wetted felt;</li> <li>a lubricant-impregnated filament is run with the wire and the wax melts due to the residual heat of the wire and the frictional heat</li> </ul>	Applicable to new and existing plants, but may be limited by customer specifications. May not be applicable in the production of fine wires
c.	Self-lubricating coatings	A solvent-containing lubrication step is avoided by using a coating system that also contains lubricant (a special wax)	
d.	High-solid enamel coating	Use of enamel coating with solid content of about 45 %. In case of fine wires, the solid content of coatings is about 30 %	

[This BAT is based on information given in Sections 9.4.3 and 9.4.4 ]

**Table 18.18: BAT-associated emissions levels (BAT-AELs) for total VOC emissions from the manufacture of winding wire**

Parameter	Product type	Unit	BAT-AEL
Total VOC emissions as calculated by the solvent mass balance	Coating of winding wire with an average diameter greater than 0.1 mm	g VOC/kg of coated wire	0.35–3

The associated monitoring is given in BAT 9.

### 18.1.9 BAT conclusions for the coating and printing of metal packaging

The emission levels for coating and printing of metal packaging given below are associated with the relevant general BAT conclusions described in Section 18.1.1.

**Table 18.19: BAT-associated emission levels (BAT-AELs) for total VOC emissions from the coating and printing of metal packaging**

Parameter	Unit	BAT-AEL
Total VOC emissions as calculated by the solvent mass balance	g VOC emitted per m <sup>2</sup> of coated surface	< 1–5

The associated monitoring is given in BAT 9.

**Table 18.20: BAT-associated emission levels (BAT-AELs) for fugitive VOC emissions from the coating and printing of metal packaging**

Parameter	Unit	BAT-AEL
Fugitive VOC emissions as calculated by the solvent mass balance	Percentage (%) of the total organic solvent input	< 1–12

The associated monitoring is given in BAT 9.

**Table 18.21: BAT-associated emission levels (BAT-AELs) for VOC emissions to air in waste gases from the coating and printing of metal packaging**

Parameter	Unit	BAT-AEL
VOC	mg C/Nm <sup>3</sup>	< 1–35

The associated monitoring is given in BAT 10.

### 18.1.10 BAT conclusions for heatset web offset printing

The BAT conclusions in this section apply to heatset web offset and apply in addition to the relevant general BAT conclusions given in Section 18.1.1.

**BAT 31. In order to reduce VOC emissions from heatset web offset printing, BAT is to use an appropriate combination of the techniques given below.**

Technique		Description	Applicability
<b>Material-based and printing techniques</b>			
a.	Use of low-IPA or IPA-free additives for dampening solutions	Reduction or avoidance of isopropanol (IPA) use as a wetting agent in heatset dampening solution, through substitution by mixtures of other organic compounds which are not VOCs and/or VOCs of a lower volatility.	May be limited by technical, training and quality requirements.
b.	Optimisation of the IPA concentration in the dampening solution	Optimise the IPA concentration in the dampening solution by adjusting water hardness and pH, continuous measurement of the IPA concentration, and using specific inks and/or plates	Generally applicable.
c.	Waterless offset plates	Use of a specific coating on the plates eliminating the need for IPA	Limited to short runs and reduces flexibility of the press.
<b>Cleaning techniques</b>			
d.	Use of non-VOC or low-volatility solvents for automatic blanket cleaning	Use of organic compounds which are not VOCs or VOCs of a low volatility as cleaning agents for automatic blanket cleaning	Generally applicable.
<b>Waste gas treatment techniques</b>			
e.	Web offset dryer integrated with waste gas treatment	A web offset dryer with an integrated WGT unit, enabling incoming dryer air to be mixed with a part of the waste gases returned from the WG thermal oxidation system.	Generally applicable for new plants. Retrofitting in existing plants may be limited by space.
f.	Treatment of air extracted from press room or press encapsulation	The dryer takes its inlet air from the press room or the press encapsulation. As a result, a part of the solvents evaporated in the press room or encapsulation are abated. This reduces the fugitive emissions.	Generally applicable.

[This BAT is based on information given in Sections 11.4.1, 11.4.2 and 11.4.3]

**Table 18.22: BAT-associated emission levels (BAT-AELs) for total VOC emissions from heatset web offset printing**

Parameter	Unit	BAT-AEL
Total VOC emissions as calculated by the solvent mass balance	Percentage (%) of the ink consumption	< 1–5

The associated monitoring is given in BAT 9.

**Table 18.23: BAT-associated emission levels (BAT-AELs) for fugitive VOC emissions from heatset web offset printing**

Parameter	Unit	BAT-AEL
Fugitive VOC emissions as calculated by the solvent mass balance	Percentage (%) of the total solvent input	< 1–10

The associated monitoring is given in BAT 9.

**Table 18.24: BAT-associated emission levels (BAT-AELs) for VOC emissions to air in waste gases from heatset web offset printing**

Parameter	Unit	BAT-AEL
VOC	mg C/Nm <sup>3</sup>	< 1–15

The associated monitoring is given in BAT 10.

### 18.1.11 BAT conclusions for flexible packaging and non-publication gravure printing

The BAT conclusions in this section apply to flexible packaging and non-publication gravure printing, and apply in addition to the relevant general BAT conclusions given in Section 1.1.1.

**BAT 32. In order to reduce the VOC emissions from flexography and non-publication gravure printing, BAT is to apply an appropriate selection of the techniques given below.**

Technique	Description	Applicability
<i>Material-based techniques</i>		
a. Co-extrusion	The printed substrate is covered with a warm, liquefied plastic film and subsequently cooled. This film replaces the varnish layer or, when used between two different layers of different carriers, acts as an adhesive	Generally applicable
<i>Printing techniques</i>		
b. Reduction of evaporation from coating processes	Evaporation can be reduced by: adequate coverage of ink fountains; using chamber doctor blades; encapsulating varnishing or lamination units (see BAT 14)	Generally applicable to automated machines.
c. Automatic and timely closure of a bypass system	The by-pass is automatically closed before make-ready press speed is reached to route off-gases to the dryer	Generally applicable
d. Removal of residual solvent in non-food printed materials	Residual solvent in the product can be minimised by increasing the drying time	Generally applicable

*[This BAT is based on information given in Sections 12.4.1 and 12.4.2]*

**Table 18.25: BAT-associated emission levels (BAT-AELs) for total VOC emissions from flexible packaging and non-publication gravure printing**

Parameter	Unit	BAT-AEL
Total VOC emissions as calculated by the solvent mass balance	Percentage (%) of the reference emissions as calculated according to Annex VII, Part 5(3.iii), to Directive 75/2010/EU	< 1–10

The associated monitoring is given in BAT 9.

**Table 18.26: BAT-associated emission levels (BAT-AELs) for fugitive VOC emissions from flexible packaging and non-publication gravure printing**

Parameter	Unit	BAT-AEL
Fugitive VOC emissions as calculated by the solvent mass balance	Percentage (%) of the total solvent input	< 1–10

The associated monitoring is given in BAT 9.

**Table 18.27: Table 18.26: BAT-associated emission levels (BAT-AELs) for fugitive VOC emissions from flexible packaging and non-publication gravure printing**

Parameter	Type of monitoring	Unit	BAT-AEL
VOCs	Continuous	mg C/Nm <sup>3</sup>	< 1–30
	Periodic		< 1–50

The associated monitoring is given in BAT 10.

### 18.1.12 BAT conclusions for publication gravure printing

The BAT conclusions in this section apply to publication gravure printing, and apply in addition to the relevant general BAT conclusions given in Section 1.1.

#### 18.1.12.1 VOC emissions

**BAT 33.** In order to reduce the VOC emissions from publication gravure printing, BAT is to apply a toluene recovery system based on adsorption in conjunction with an appropriate combination of the techniques given below.

Technique	Description	Applicability
<b>Material-based techniques</b>		
a. Use of retention inks	Use of retention inks slows the film formation and toluene release so more toluene is released in the dryer	Generally applicable
<b>Waste gas extraction and treatment techniques</b>		
b. Increased temperature in the press room	With higher temperatures in the press room, more toluene will evaporate from the residues in the printed product. The press room air is extracted and sent to treatment.	Only applicable where press room off-gases are extracted and sent to treatment
c. Increasing drying time	Increasing drying time and maintaining the same speed can be achieved by increasing the length of the residence time in the dryer	Applicable to new presses
<b>Cleaning techniques</b>		
d. Automatic cleaning systems connected to the toluene recovery system	In-press automated cylinder cleaning with air extraction to the toluene recovery system	Generally applicable

[This BAT is based on information given in Sections 13.4.1 and 13.4.2]

**Table 18.28: BAT-associated emission levels (BAT-AELs) for total VOC emissions from publication gravure printing**

Parameter	Unit	BAT-AEL
Total emissions of volatile organic compounds as calculated by the solvent mass balance	Percentage (%) of the total solvent input	< 1–5

The associated monitoring is given in BAT 9.



**Table 18.29: BAT-associated emission levels (BAT-AELs) for fugitive VOC emissions from publication gravure printing**

Parameter	Unit	BAT-AEL
Fugitive VOC emissions as calculated by the solvent mass balance	Percentage (%) of the total solvent input	< 1–3

The associated monitoring is given in BAT 9.

**Table 18.30: BAT-associated emission levels (BAT-AELs) for VOC emissions in waste gases to air from publication gravure printing**

Parameter	Unit	BAT-AEL
VOC	mg C/Nm <sup>3</sup>	< 5–35

The associated monitoring is given in BAT 10

## 18.2 BAT conclusions for the preservation of wood and wood products with chemicals

### 18.2.1 General BAT conclusions for all WPC activities

#### 18.2.1.1 Environmental management systems

*(The following description of the general EMS features is based on standard text agreed at the level of the IED Article 13 Forum and used in recent documents such as the BAT conclusions for CWW, IRPP, NFM, REF. In view of the recent changes to ISO 14001 and EMAS there are discussions on a new standard text. The new text will be used for the final version. The possibilities for changes are therefore limited to the section specifically for WPC issues.)*

**BAT 34. In order to improve the overall environmental performance, BAT is to implement and adhere to an Environmental Management System (EMS) that incorporates all of the following features:**

- i. commitment of the management, including senior management;
- ii. definition, by the management, of an environmental policy that includes the continuous improvement of the environmental performance of the installation;
- iii. planning and establishing the necessary objectives, targets and procedures, in conjunction with financial planning and investment;
- iv. implementation of procedures paying particular attention to:
  - (a) structure and responsibility;
  - (b) recruitment, training, awareness and competence at all levels;
  - (c) communication internally and externally;
  - (d) employee involvement;
  - (e) documentation;
  - (f) effective process control;
  - (g) maintenance programmes;
  - (h) emergency preparedness and response;
  - (i) safeguarding compliance with environmental legislation;
- v. checking performance and taking corrective action, paying particular attention to:
  - (a) monitoring and measurement (see also the JRC Reference Report on Monitoring of Emissions to Air and Water from IED Installations – ROM);
  - (b) corrective action;
  - (c) maintenance of records;
  - (d) independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained.
- vi. review, by senior management, of the EMS and its continuing suitability, adequacy and effectiveness;
- vii. following the development of cleaner technologies;
- viii. consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;
- ix. application of sectoral benchmarking on a regular basis.

Specifically for wood preservation with chemicals, it is also important to consider the following features of the EMS:

- Keeping up-to-date with the developments in legislation regarding biocides and creosote, especially with regard to authorisation of products under REACH, and with

developments in biocidal products with a view to adapting treatment process and/or chemicals used to using the most environmental friendly.

- Inclusion of a raw material evaluation system to reduce the use of environmentally harmful substances and of a plan to optimise the use of solvents in the process.
- Inclusion of a solvent mass balance to measure and manage emissions for solvent-based and creosote treatment.
- Identification and listing of all environmentally critical process and abatement equipment (whose failure could impact on the environment).
- Preparation and implementation of plans for the prevention and control of leaks and spillages, including waste management guidelines for dealing with waste arising from spillage control.
- Written scheme of inspection and maintenance for the plant and equipment, including checks for integrity and correct functioning containment/bunds, safety locks, valves and alarms, tightness of valves and ductwork, check for visible drips/spillages.
- Emergency plans for fire, accidental spills, etc.
- Record of accidental leakages and spillages, and improvement plans (counter measures).
- Consideration of decommissioning during design and operational phase including measures and provision of sufficient funds for site remediation.

*[This BAT conclusion is based on information given in Section 15.4.1.1.1]*

#### 18.2.1.2 Substitution of harmful/hazardous substances

**BAT 35. In order to avoid the emission of biocides and/or solvents, BAT is to apply one of the techniques given below.**

	Technique	Description
a.	Chemical wood modification (CWM)	The chemical modification of wood is a biocide- and solvent-free process which induces a reaction between an introduced molecule and the wood polysaccharides, creating a permanent change throughout an entire section of wood. Current commercial processes include acetylation (full sapwood and heartwood impregnation with an acetic solution) and furfurylation (full sapwood and heartwood penetration with a solution of furfuryl alcohol derived from plant waste)
b.	Thermal wood modification	Thermal modification is a biocide- and solvent-free process which induces a permanent change in the polysaccharides (e.g. starch and cellulose) of the wood to enhance its performance. Wood is heated to a temperature in excess of 160 °C in an environment in which oxygen is restricted or eliminated to achieve the desired performance characteristic without charring of the surface
c.	Supercritical carbon dioxide process	The supercritical carbon dioxide process is a pressure impregnation process in which supercritical CO <sub>2</sub> is used as a carrier for the preservatives/active substances (instead of liquid organic solvents), thus resulting in a solvent-free process
d.	Substitution of solvent-containing preservatives with water-based preservatives	Solvents or creosote are replaced by water as the carrier for the biocides

**Applicability**

Techniques (a) to (d) are only applicable to new plants or major upgrades of existing plants. The applicability may be restricted due to product quality requirements.

*[This BAT conclusion is based on information given in Section 15.4.1.2]*

**BAT 36. In order to reduce the environmental risk posed by the use of biocides, BAT is to substitute potentially harmful preservatives/treatment chemicals with less hazardous preservatives/treatment chemicals.**

*[This BAT conclusion is based on information given in Section 15.4.1.2.5]*

**18.2.1.3 Plant design / precautionary measures**

**BAT 37. In order to protect soil and groundwater, BAT is to apply all of the techniques given below.**

	<b>Technique</b>	<b>Description</b>
a.	Plant and equipment containment or bund	The parts of the plant that store or handle treatment chemicals or solvents, i.e. solvents and treatment chemicals storage area, treatment area (comprising treatment vessel, working vessel, unloading/pull out facilities, dripping/drying, cooling zone), pipes and ductwork for solvents and/or treatment chemicals, creosote (re)conditioning facilities are contained or banded. Containments and bunds are sealed, with impermeable surfaces, resistant to wood preservatives and with sufficient capacity to capture and hold the wood preservative volumes handled or stored in the plant / contained equipment. Containments/bunds are inspected and maintained regularly
b.	Drip tray	Collection device made of preservative-resistant material for collecting and recovering drips and spills of treatment chemicals placed under equipment or processes where drips may occur (i.e. valves, inlets/outlets of storage tanks, treatment vessels, working tanks, unloading/pull-out zones, handling of freshly treated wood, cooling/drying zone). The collected preservative solution is recirculated into the treatment chemicals system
c.	Soil/floor sealing	Sealed hardcover surface for areas where drippage, spills or accidental releases of preservatives/treatment chemicals or solvents may occur
d.	Pressure-reducing valves for high-pressure pipes connected to mixing tanks	
e.	Alarms/warning systems for equipment identified as 'critical'	'Critical' equipment is equipped with alarms/warning systems to indicate malfunctions or breakdown. These alarms/warning systems are maintained and checked regularly to ensure continued correct operation

*[This BAT conclusion is based on information given in Sections 15.4.1.3.2, 15.4.1.3.5 to 15.4.1.3.7 and 15.4.1.3.9]*

#### 18.2.1.4 Material management and good house keeping

**BAT 38.** In order to reduce the environmental impact and risk associated with the use of biocides and solvent-containing preservatives, BAT is to reduce the consumption of preservatives/treatment chemicals by applying all of the techniques given below.

	Technique	Description	Applicability
a.	Use of an efficient preservative application system	Application systems where the wood is immersed in the preservative solution have a higher efficiency than, for example, spraying. The application efficiency of vacuum processes (closed system) is close to 100 %	Only applicable to new plants or in case of major upgrades.
b.	Control and optimised consumption of chemicals for the described end use	Control of consumption of treatment chemicals by: a) weighing of the wood/wood product before and after impregnation or b) calculation and verification of the impregnation rate during and after impregnation (requiring measurement of liquid levels in vessels and tanks) and not exceeding retention rates required by product quality standards or suppliers recommendations	Generally applicable
c.	Solvent mass balance	The compilation, at least on an annual basis, of organic solvent inputs and outputs of a plant as defined in Part 7 of Annex VII to Directive 2010/75/EU	Only applicable to plants using solvent-based preservatives or creosote.

*[This BAT conclusion is based on information given in Sections 15.4.1.3.9 to 15.4.1.3.11]*

#### 18.2.1.5 Organisational and operational techniques to improve the environmental performance of wood preservation with chemicals

**BAT 39.** In order to prevent or reduce emissions from wood preservation with chemicals, BAT is to conduct regular inspections and maintenance of plant and equipment.

##### Description

The plant and equipment are regularly inspected and serviced to ensure proper functioning; this includes especially the check of the integrity and/or leak-free status of valves, pumps, pipes, tanks, pressure vessels, drip trays, containment facilities and bunds and the functionality of alarms/warning systems.

*[This BAT conclusion is based on information given in Section 15.4.1.4.1]*

**BAT 40.** In order to prevent the contamination of areas (surfaces) of the plant normally not in contact with preservatives/treatment chemicals, BAT is to use dedicated transport vehicles for potentially contaminated areas or a crane system for handling wood and to restrict access to potentially contaminated areas and/or to provide grit walkways.

*[This BAT conclusion is based on information given in Sections 15.4.1.4.4 to 15.4.1.4.6]*

### 18.2.1.6 Waste minimisation, management and on-site treatment

**BAT 41.** In order to prevent or reduce the generation of waste, especially of hazardous waste, from wood preservation with chemicals, BAT is to use all of the techniques (a) to (e) and a suitable combination of techniques (f) to (h) given below.

	Technique	Description
a.	Removal of debris from the wood/wood products before treatment	Debris is removed from the surface of the wood/wood products by blowing air through the batch of wood to be treated
b.	Removal of plastic wrapping from timber prior to treatment	
c.	Measurement of wood moisture before treatment	Wood moisture is measured by electric resistance measurement or by weighing procedures to optimise the impregnation process and ensure the required product quality
d.	Recirculation of collected drippage and spills of preservative/treatment chemicals	Drippage and spills of preservatives/treatment chemicals collected from drip pads or sealed surfaces are recirculated to the preservatives/treatment chemicals system
e.	Recirculation of wax and oils	Surplus wax or oils from the impregnation process is collected and recirculated
f.	Delivery of treatment chemicals or solvents in bulk to eliminate packaging	
g.	Cleaning of redundant preservative containers	Containers that still contain residues of the preservatives are rinsed and cleaned. The cleaning water is reused for preparation of water-based preservative/treatment chemicals solutions
h.	Delivery of treatment chemicals or solvents in reusable containers	Containers (IBCs) are returned to the supplier for reuse

*[This BAT conclusion is based on information given in Sections 15.4.2.2.2 to 15.4.2.2.4, 15.4.1.5.1 to 15.4.1.5.3 and 15.4.2.7.1]*

**BAT 42. In order to reduce the amount of (hazardous) waste and the environmental risks, especially from hazardous waste, BAT is to apply all of the techniques given below.**

	<b>Technique</b>
a.	Separation of hazardous and non-hazardous waste at source and separate storage
b.	Storage of waste on sealed surfaces and in suitable containers
c.	Designated, weather-protected area for storage of hazardous wastes/Bunded storage area for hazardous waste protected from surface run-off water and protected from rain (roofing)
d.	Disposal by authorised facilities

*[This BAT conclusion is based on information given in Sections 15.4.1.5.4 to 15.4.1.5.8]*

### **18.2.1.7 Water and waste water management (emissions to water)**

**BAT 43. In order to reduce the volume of waste water contaminated with biocides and/or solvents, BAT is to avoid contact of uncontaminated rain and surface run-off water with areas where preservatives are stored, handled or used, with treated wood and with contaminated water by applying an appropriate combination of the techniques given below.**

	<b>Technique</b>	<b>Description</b>
a.	Drainage channels	A drainage channel around the WPC plant stops rain and surface run-off water from entering plant areas and thus from being contaminated
b.	Outer kerb bund	An elevated rim around the whole plant or parts of the plant stops rain and surface run-off water from entering plant areas and thus from being contaminated
c.	Roofing with roof guttering	A roof protects the solvents and treatment chemicals storage area, the treatment area and/or the post-treatment area from rainwater. The run-off water from the roofs is collected by roof guttering and channelled away from potential sources of contamination

*[This BAT conclusion is based on information given in Sections 15.4.1.6.1]*

**BAT 44. In order to reduce fresh water consumption and to reduce emissions to water, BAT is to collect surface run-off water and to use it in the preparation of wood preservative solutions.**

#### **Applicability**

Applicable to plants with water-based preservative treatment on site.

*[This BAT conclusion is based on information given in Sections 15.4.1.3.6]*

**BAT 45.** In order to prevent or reduce the emissions to water from wood preservation with chemicals, BAT is to separately collect surface run-off water from areas that are potentially contaminated with preservatives or solvents and to apply technique (a) or a suitable combination of techniques (b), (c) and (d) given below.

	Technique	Description
a	Reuse of collected surface run-off water	Potentially contaminated surface run-off water is collected and reused completely for the preparation of water-based preservative solution
b	Assessment of the quality of the collected surface run-off water	Measurement of the concentration of pertinent pollutants based on the preservative type and biocides used in the treatment, e.g. solvents, specific active substances, metals
c	Treatment of waste water	Where a pollutant load in the collected surface run-off water is detected or can be expected, the waste water is treated in a WWTP (on or off site)
d	Disposal as hazardous waste	Where a pollutant load in the collected surface run-off water is detected or can be expected, and where treatment or reuse is not feasible, the collected surface run-off water is disposed of as hazardous waste

[This BAT conclusion is based on information given in Section 15.4.1.6.1 to 15.4.1.6.4]

### 18.2.1.8 Monitoring

#### 18.2.1.8.1 Emissions to water and groundwater

**BAT 46.** BAT is to monitor the pollution load in waste water and potentially contaminated surface run-off water before discharge in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Parameter	Standard(s)
Biocides <sup>(1)</sup>	NI
Cu <sup>(2)</sup>	NI
Cr <sup>(2)</sup>	Cr <sub>total</sub> : various EN standards available (e.g. EN ISO 11885, EN ISO 17294-2, EN ISO 15586)
Solvents <sup>(3)</sup>	NI
PAHs <sup>(4)</sup>	NI
Benzo[a]pyrene <sup>(4)</sup>	NI
HOI (oil)	EN ISO 9377-2:2000

<sup>(1)</sup> Specific substances depending on the biocides/active substances currently used in the process.  
<sup>(2)</sup> If currently used in the process.  
<sup>(3)</sup> For plants applying solvent-based treatment; specific substances depending on the solvents currently used in the process.  
<sup>(4)</sup> For plants applying creosote treatment.

[This BAT conclusion is based on information given in Sections 15.4.1.8.1]



**BAT 47. BAT is to monitor the pollution load in groundwater at least twice per year and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.**

Parameter	Standard(s)
Biocides <sup>(1)</sup>	NI
As <sup>(2)</sup>	NI
Cu <sup>(2)</sup>	NI
Cr <sup>(2)</sup>	Cr <sub>total</sub> : various EN standards available (e.g. EN ISO 11885, EN ISO 17294-2, EN ISO 15586)
Solvents <sup>(3)</sup>	NI
PAHs <sup>(4)</sup>	NI
Benzo[a]pyrene <sup>(4)</sup>	NI
HOI (oil)	EN ISO 9377-2:2000
<sup>(1)</sup> Specific substances depending on the biocides/active substances currently or previously used in the process. <sup>(2)</sup> If currently or previously used in the process. <sup>(3)</sup> If currently or previously used in the process; specific substances depending on the solvents used in the process. <sup>(4)</sup> If currently or previously used in the process. Note: parameters may be eliminated from the list, if not used in the process or if there is no historic contamination of soil by the substance.	

[This BAT conclusion is based on information given in Sections 15.4.1.8.3]

#### 18.2.1.8.2 Emissions to air in waste gases

**BAT 48. BAT is to monitor emissions to air in waste gases with at least the frequency given below and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.**

Parameter	Activity	Standard(s)	Minimum monitoring frequency	Monitoring associated with BAT
TOC	Creosote and solvent-based plants	EN 12619	Once every year	68
PAH	Creosote plants	ISO 11338-1, ISO 11338-2	Once every year	68
NO <sub>x</sub> <sup>(1)</sup>	Creosote and solvent-based plants	EN 14792	Once every year	69
CO <sup>(1)</sup>	Creosote and solvent-based plants	EN 15058	Once every year	69
<sup>(1)</sup> Only related to thermal treatment techniques of waste gases.				

[This BAT conclusion is based on information given in Sections 15.4.1.8.5 and 15.4.3.3.5 to 15.4.3.3.10]

**18.2.1.9 Decommissioning**

**BAT 49.** In order to facilitate decommissioning and reduce the environmental impact of WPC plants upon definitive cessation of operation, BAT is to apply all of the techniques given below.

	<b>Technique</b>	<b>Description</b>
a	Consideration of decommissioning during design and operational phase including provision of sufficient funds for site remediation	
b	Baseline report	Report on the state of soil and groundwater contamination by relevant hazardous substances
c	Avoiding underground storage and ductwork	
d	Recording underground facilities and keep a record of incidents that may cause soil and/or groundwater pollution	

[This BAT conclusion is based on information given in Sections 15.4.1.1.1, 15.4.1.3.1 and 15.4.1.4.2]

**18.2.1.10 Noise**

**BAT 50.** In order to prevent or, where that is not practicable, to reduce noise emissions, BAT is to use one or a combination of the techniques given below.

<b>Technique</b>	
<b><i>Storage and handling of raw materials</i></b>	
a	Installation of noise walls and utilisation/optimisation of the noise-absorbing effect of buildings
b	Enclosure or partial enclosure of noisy operations
c	Use of low-noise vehicles / transport systems
d	Noise management measures
<b><i>Kiln drying</i></b>	
a	Noise reduction measures for fans

[This BAT conclusion is based on information given in Sections 15.4.1.9]

**18.2.2 Production-step-specific BAT conclusions for wood preservation with chemicals****18.2.2.1 Delivery, storage and handling of solvents and treatment chemicals**

**BAT 51.** In order to reduce the emissions from delivery, storage and handling of solvents and treatment chemicals, BAT is to apply technique (a) or (b) and all of the techniques (c) to (g) given below.

	<b>Technique</b>	<b>Description</b>
a	Back-venting displaced air to the delivery tank during filling of tanks	
b	Capture of displaced air during filling of tanks and treatment of these off-gases	
c	Light coloured paint coating to reduce heating up of stored chemicals (for above-ground storage tanks for creosote)	
d	Delivery connections to storage tanks located within bunded/contained area fixed and locked when not in use	

e	Volume indicators, overfilling alarms and automatic overflow switches	Tanks fitted with audible and/ or visual high-level alarms or volume indicators to warn of overfilling
f	Deliveries to bulk storage tanks supervised by trained personnel to avoid potential accidents and spillage	
g	Closed storage containers for materials containing solvents and/or biocides.	

[This BAT conclusion is based on information given in Section 15.4.2.1]

### 18.2.2.2 Preparation /Conditioning of Wood: kiln drying

**BAT 52.** In order to reduce the emissions to water from kiln drying, BAT is to collect and treat condense water.

**Description** (to be added)

[This BAT conclusion is based on information given in Sections 15.4.2.2.1]

**BAT 53.** In order to reduce the consumption of preservatives/treatment chemicals and energy, to reduce the generation of waste and to reduce emissions of preservatives/treatment chemicals, BAT is to optimise the wood charge preparation by applying a suitable combination of the techniques given below.

	Technique	Applicability
a	Separation of wood in packs by spacers	Generally applicable
b	Sloping of wood packs in traditional horizontal treatment vessels	Generally applicable
c	Use of tilting pressure treatment vessels	Only applicable to new plants or in case of major revamps
d	Positioning shaped profiles in a way so as to prevent ponding/trapping of treatment solution	Generally applicable
e	Securing wood packs/pieces to prevent wood lifting during treatment	Generally applicable
f	Avoiding flat areas or trap areas on loading systems	Generally applicable
g	Maximising wood load	Generally applicable

[This BAT conclusion is based on information given in Section 15.4.2.2.5]

### 18.2.2.3 Preservative application process / Non-pressure processes

**BAT 54.** In order to prevent accidental leakage and emissions of preservatives/treatment chemicals, BAT is to apply both techniques given below for treatment vessels.

	Technique	Applicability
a	Double-walled impregnation tanks with leak detection device	New plants and in the case of major plant upgrades
b	Sufficiently large and wood-preservative-resistant containment, fender and automatic leak detection device in the case of non-visible containment	Applicable to existing single-wall treatment vessels

[This BAT conclusion is based on information given in Sections 15.4.2.3.3 and 17.4.2.3.4]

**BAT 55.** In order to avoid the emission to soil, groundwater and water of preservatives/treatment chemicals in the form of drippage from the treated wood, BAT is to apply all of the techniques given below.

	Technique	Description
a)	Sufficient dripping time after treatment	Treated wood is held above the treatment vessel for some time after the treatment to allow the surplus preservatives to drip back into the treatment vessel
b)	Drip test	Treated wood/wood packs are lifted by mechanical means and suspended above the post treatment drying area for a minimum of 5 minutes. If no drippage of treatment solution occurs, the wood is deemed dry.
c)	Removal of treated wood from the contained area only once the wood is deemed 'dry'	

[This BAT conclusion is based on information given in Sections 15.4.2.3.5 and 15.4.2.3.6]

**BAT 56.** In order to reduce the emissions from wood treatment using spraying, spray tunnels or bath treatments, BAT is to enclose the treatment and apply off-gas extraction and an emission abatement system.

#### Description

Spraying/spray tunnels: spraying units are sealed against the ambient air.

Bath treatments: stationary enclosure with doors to open for loading/unloading is installed over the impregnation trough. The off-gas is extracted during the whole impregnation process and during cooling of wood (creosote hot-cold bath treatment).

[This BAT conclusion is based on information given in Sections 15.4.2.3.1, 15.4.2.3.2 and 15.4.3.3.6]

#### 18.2.2.4 Preservative application process / Pressure processes

**BAT 57.** In order to avoid or reduce the emission of preservatives/treatment chemicals or solvents from pressure processes (autoclaves), BAT is to use all of the techniques given below.

	Technique	Description
a	Safety lock for vessel door	The treatment vessel is locked shut and sealed once the wood pack/vessel loading system is loaded and before treatment takes place. Process controls are in place that prevent the operation of the treatment vessel unless the vessel is locked and sealed
b	Process controls displaying whether liquid is present in the treatment vessel	
c	Process controls prevent the treatment vessel from opening before all preservative solution is removed from the treatment vessel	Process controls prevent the opening of the treatment vessel while it is still pressurised and/or filled

d	Catch-lock for the treatment vessel door	The door of the treatment vessel is equipped with a catch-lock to prevent the release of fluid in case the treatment vessel door needs to be opened in an emergency situation.
e	Safety pressure-relief valves	Treatment vessels are fitted with safety relief valves to allow emptying of vessel in a controlled manner. The valves are designed to ensure that any discharge is directed to a tank of sufficient capacity.  Pressure/vacuum-relief valves are examined at least once every six months for signs of corrosion, contamination, incorrect fitting and to be cleaned and/or corrected as required.
f	Control of aerosol emissions from vacuum pump exhaust	Air extracted from pressure treatment vessels (vacuum pump outlet) is treated by liquid separators or is directed to a settling tank.
g	Reduction of aerosol emissions (when opening the treatment vessel) by allowing sufficient time between depressurisation and opening of the treatment vessel	
h	Application of final vacuum to remove excess preservatives	Emissions when opening the treatment vessel are reduced by applying a final vacuum that removes all surplus treatment solution

*[This BAT conclusion is based on information given in Sections 15.4.2.4]*

**BAT 58. In order to reduce the energy consumption from pressure processes, BAT is to apply variable pump control.**

#### **Description**

After reaching the required working pressure, the system is switched to a pump with reduced performance and energy consumption.

*[This BAT conclusion is based on information given in Sections 15.4.2.4.7]*

#### **18.2.2.5 Post-treatment conditioning and interim storage**

**BAT 59. In order to avoid or reduce the contamination of soil or groundwater from the interim storage of freshly treated wood, BAT is to apply all of the techniques given below.**

	<b>Technique</b>
a.	Weather protection (roofing)
b.	Sealed surfaces resistant to attack by preservatives/treatment chemicals
c.	Collection of drippage and recirculation to preservative system

*[This BAT conclusion is based on information given in Sections 15.4.2.6]*

#### **18.2.2.6 Impregnation with hydrophobing agents**

**BAT 60. In order to reduce the consumption and emission of hydrophobing agents (such as wax or oil), BAT is to recirculate wax and oils.**

*[This BAT conclusion is based on information given in Sections 15.4.2.7]*

### 18.2.2.7 Cleaning of treatment equipment

**BAT 61.** In order to reduce the water consumption and the emissions to water from cleaning, BAT is to apply rotary spray nozzle heads or similar for the cleaning of treatment equipment and to reuse the water in the treatment process.

#### **Applicability**

Recirculation of water is only possible for plants with water-based treatment on site.

*[This BAT conclusion is based on information given in Sections 15.4.2.5.1]*

### 18.2.2.8 Storage of treated wood

**BAT 62.** In order to prevent or reduce the contamination of soil or groundwater from storage of wood treated with non-fixating preservatives, BAT is to store the wood on sealed surfaces protected from the weather (i.e. with a roof).

*[This BAT conclusion is based on information given in Sections 15.4.2.7]*

## 18.2.3 Preservative-type-specific BAT conclusions

### 18.2.3.1 Water-based preservatives

**BAT 63.** In order to reduce water consumption and emissions to water, BAT is to recirculate waste water, spillages of water-based preservatives and surface run-off water into the preservative system (make-up water).

Water-based wood preservation plants can be operated waste-water-free.

*[This BAT conclusion is based on information given in Sections 15.4.3.1.2]*

**BAT 64.** In order to reduce the environmental risks from the use of chromium-containing preservatives, BAT is to substitute the preservatives with chromium-free preservatives.

*[This BAT conclusion is based on information given in Sections 15.4.3.1.1]*

### 18.2.3.2 Solvent-based preservatives

**BAT 65.** In order to reduce the environmental impact of the use of solvent-containing preservative solutions, BAT is to use solvents with a lower photochemical ozone creation potential.

*[This BAT conclusion is based on information given in Sections 15.4.3.2.2]*

**BAT 66.** In order to reduce the emissions to air, BAT is to enclosing solvent-based wood preservation process, extract off-gases and apply emission abatement techniques .

*(Information provided on BAT candidates applicable for SB preservatives and on the related emission levels (no plant-specific data was submitted), currently does not allow for specific BAT conclusions or BAT AEPLs for SB plants.)*

[This BAT conclusion is based on information given in Sections 15.4.3.2.2]

### 18.2.3.3 Creosote

**BAT 67.** In order to reduce emissions of organic substances to air and of odour from creosote treatment, BAT is to use low-emission impregnating oils, i.e. Grade C creosote instead of Grade B or mixtures where creosote is partially replaced by other substances, e.g. linseed oil, biocides and other auxiliary substances.

#### Applicability

Applicability for the use of Grade C creosote may be limited for low ambient temperatures.

[This BAT conclusion is based on information given in Sections 15.4.3.3.1 and 15.4.3.3.2]

**BAT 68.** In order to reduce emissions of VOCs and PAH, to air from wood preservation using creosote, BAT is to enclose emitting equipment or processes and to apply off-gas extraction and one of the abatement techniques given below.

	Technique	Description
a.	Thermal oxidation	Oxidation of VOCs in a simple oxidation chamber by chemical reaction with oxygen without heat recovery
b.	Combustion	VOC-containing off-gases are incinerated, e.g. in a biomass boiler
c.	Adsorption using activated carbon	VOCs are adsorbed on the surface of activated carbon
d.	Wet scrubbing	Wet scrubbing (or absorption) is a mass transfer between a soluble gas or dust and a solvent – often water – in contact with each other

**Table 18.31: BAT-associated emission levels (BAT-AELs) for emissions of VOC, PAH emissions to air in waste gases to air from creosote plants**

Parameter	BAT-AEL	Unit
VOCs <sup>(1)</sup>	<1–4 <sup>(2)</sup>	mg C/Nm <sup>3</sup>
PAH	< 1	mg/Nm <sup>3</sup>
<sup>(1)</sup> Measured as TOC in accordance with monitoring standard EN 12619:2013.		
<sup>(2)</sup> O <sub>2</sub> reference level for plants applying thermal oxidation or other combustion processes: 18 %.		

The associated monitoring is given in BAT 48.

[This BAT conclusion is based on information given in Sections 15.4.3.3.5 to 15.4.3.3.10]

**BAT 69.** In order to prevent or reduce NO<sub>x</sub> emissions to air while limiting CO emissions from the thermal treatment of off-gases, BAT is to apply one or both of the techniques given below.

	Technique	Description
a.	Optimisation of thermal treatment conditions	Measures are taken to maximise the efficiency of VOC destruction while keeping NO <sub>x</sub> emissions as low as possible. This is achieved by a combination of techniques including good design of the combustion equipment, optimisation of the temperature and residence time in the combustion zone, and/or use of an advanced control system (a computer-based system to control the combustion efficiency).
b.	Use of low-NO <sub>x</sub> burners	The technique is based on the reduction of the peak flame temperature in the combustion chamber, delaying but completing the combustion and increasing the heat transfer (increased emissivity of the flame). It is combined with increased residence time in order to achieve the desired VOC destruction.

**Table 18.32: BAT-associated emission levels (BAT-AELs) for NO<sub>x</sub> emissions to air from the thermal treatment of off-gases**

Parameter	Process	Unit	BAT-AEL <sup>(1)</sup> at 18 % O <sub>2</sub>
NO <sub>x</sub>	Thermal treatment of off-gases	mg/Nm <sup>3</sup>	33–226

The associated monitoring is given in BAT 48.

As an indication, the CO emission levels associated with the above techniques will generally be as indicated in Table 18.33.

**Table 18.33: Indicative levels for CO emissions to air from the thermal treatment of off-gases**

Parameter	Process	Unit	Indicative emission level
CO	Thermal treatment of off-gases	mg/Nm <sup>3</sup>	105–148

The associated monitoring is given in BAT 48.

**BAT 70.** In order to reduce the emissions to air and to water from the depressurisation and vacuum operation of the treatment vessel and from creosote (re)conditioning, BAT is to collect and treat the condensates using an activated carbon filter.

#### Description

Condensate volumes are collected, allowed to settle and treated in an activated carbon filter. The treated water is either reused (closed circuit) or discharged to the public sewer system.

*[This BAT conclusion is based on information given in Sections 15.4.3.3.3]*



## 19 EMERGING TECHNIQUES FOR SURFACE TREATMENT USING SOLVENTS

***TWG please update with fresh information***

An emerging technique is understood in this document as a novel technique that has not yet been applied in any industrial sector on a commercial basis. This section contains those techniques that may appear in the near future and that may be applicable to the surface treatment using organic solvents sector.

### 19.1 Printing/coating

#### 19.1.1 UV curing flexography

##### **Description**

It is likely that UV curing flexo printing, for purposes other than beverage cartons, will be developed in the future.

##### **Achieved environmental benefits**

Reduced VOC use and emissions.

##### **Cross-media effects**

No data submitted.

##### **Operational data**

No data submitted.

##### **Applicability**

No data submitted.

##### **Economics**

No data submitted.

##### **Driving force for implementation**

No data submitted.

##### **Example plants**

No data submitted.

##### **Reference literature**

[38, TWG, 2004]

## 19.2 Winding wire manufacture

### 19.2.1 Water-based enamel coatings

*Ex chapter 3.4.5.2*

#### **Description**

Tests were performed with acrylic enamels some years ago. They did not meet the required IEC standard and the increasing requirements for electrical and mechanical performance needed by the customer. A small amount of solvent (up to 15 % alcohols and amines) is necessary to maintain surface performance.

#### **Achieved environmental benefits**

A significant reduction of solvent emissions.

#### **Cross-media effects**

Emissions to water, and a huge increase of energy input needed due to drying and energy recovery from the incinerator is omitted.

#### **Operational data**

First experiences show a need for greater material input and a longer drying time. Due to the high costs and technological aspects this alternative is not yet proven as suitable. The use of water-based systems requires higher energy consumption to ensure a longer, and hotter, drying zone. Furthermore, the installations have to be equipped with stainless steel pipes.

#### **Applicability**

This is not currently applicable.

#### **Economics**

Low cost benefit. Retrofitting is a high cost operation because all pipes have to be replaced by stainless steel material. Also the drying zone has to be changed (longer/warmer).

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

No data submitted.

#### **Reference literature**

[28, EWWG, 2004] [78, TWG, 2005]

### 19.2.2 UV curing enamel coatings

*Ex chapter 3.4.5.3*

#### **Description**

UV curing enamel coatings might be a possible alternative for conventional solvent-based enamel coatings.

#### **Achieved environmental benefits**

Solvent emissions from the coating system are reduced to zero.

#### **Cross-media effects**

UV lamps are needed for the drying. High energy consumption.

#### **Operational data**

The existing materials will not meet the required specifications. Great problems are anticipated in order that the correct thickness is reached, and the creation of blisters will cause a bad electrical performance. The UV curing enamels have an unpleasant odour and workers might be allergic to them. Furthermore the used acrylates cannot fulfil the required temperature resistance.

Due to the lack of performance, high costs, and technological and safety aspects, this alternative is not yet proven as suitable.

**Applicability** ~~Until now, this method/process has not been used. There are currently some development activities which are supported by the EU; however, results are not encouraging at this time.~~

The method/process has not been used in practice yet. There is some on-going development activity, and one pilot plant has been set up. [Nexans 2004]

#### **Economics**

Low cost benefit. Retrofitting is an expensive operation. High material costs are also expected.

#### **Driving force for implementation**

No data submitted.

#### **Example plants**

No data submitted.

#### **Reference literature**

[12, UBA Germany, 2002] [28, EWWG, 2004] [78, TWG, 2005]

### **19.2.3 Hot melt enamel coatings**

*Ex chapter 3.4.6.2*

#### **Description**

A thermosetting material is applied to the copper conductor. This substitute is thermoplastic until 100 °C, and then the resin is maintained as liquid at approximately 80 °C and can be applied with dies onto the copper conductor.

Tests have been performed, especially with wire diameters >0.355 mm, but all wires could not satisfy the typical and increasing demands of modern wire processing regarding adherence and flexibility, heat-shock, cut-through, thermal resistance, resistance to abrasion and centricity of insulation film. Due to the nearly 100 % solids content and the resulting number of fewer insulation layers, it is not possible to realise small tolerances of film thicknesses in a precise way. Fewer layers and bad centricity cause worsening to the dielectric strength of the insulation film.

#### **Achieved environmental benefits**

Since this is an almost solvent-free process, a significant reduction in solvent emissions can be achieved.

#### **Cross-media effects**

The hot melts still contain small quantities of alcoholic substances which cause a flue smell by oxidation and cracking during the enamelling process. A high input of electrical energy is required for curing.

#### **Operational data**

The application of the hot melts requires temperatures of about 80 to 100 °C in the resin circulating pumps, which could result in some problems in the working area for the workers.

No recovery of energy is possible from the oven, due to the lack of solvent.

**Applicability**

Not the whole range of current products can be produced by using hot melts. There is no solution for a direct (1:1) replacement of the existing insulating systems. Tests have been performed since the mid-1990s without success. This technique is not applicable for wire sizes below 0.15 mm, as the wire will break because of the viscosity of the molten polymer. Due to the lack of performance, high costs, and technological and safety aspects, this alternative is not yet proven as suitable.

**Economics**

Low cost benefit. The machinery has to be completely changed from the existing one. New insulation materials have to be developed, tested by the winding wire manufacturer and approved by the customers.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[28, EWVG, 2004] [38, TWG, 2004] [78, TWG, 2005]

### 19.2.4 Waxing of fine wires

**Description**

Techniques are being considered to reduce the solvents emission from the final drying of wax on fine wires (0.01–0.1 mm.).

**Achieved environmental benefits**

Reduction of VOC consumption and emissions.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[38, TWG, 2004].

## 19.3 Manufacture of abrasives

### 19.3.1 ~~[High speed drying and hardening processes]~~

*Info from the industry: After several tests and further investigations these techniques turned out to be not applicable in the abrasive industry- TWG please confirm*

**Description:** ~~For several years, patents have been established aiming at faster drying and hardening of the bond materials. The new processes include, for example, the application of UV radiation or microwaves.~~

**Achieved environmental benefits:** No data submitted.

**Cross media effects:** No data submitted.

**Operational data:** No data submitted.

**Applicability:** ~~Within the next few years, none of the present developments will change or influence the production processes at existing abrasive production plants.~~

**Economics:** No data submitted.

**Driving forces for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** No data submitted.

## 19.4 Manufacture of adhesive tape

No data submitted.

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## 19.5 Coating of cars and light vans

[13, DFIU and IFARE, 2002] [38, TWG, 2004]

### 19.5.1 Improved water-dilutable one- and two-component clear coating

#### Description

New products in the form of improved water-dilutable one- and two-component clear coating systems as well as 'very high solid' two-component clear coating systems (with a solids content of up to 90 wt-%) are expected in the future.

#### Achieved environmental benefits

No data submitted.

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

No data submitted.

#### Economics

No data submitted.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

No data submitted.

### 19.5.2 Developments in powder coating

#### Description

The application of powder topcoating on a larger scale is expected. According to statements from paint producers, a variety of pigmented finish coating systems based on powder are already available; however, these are not yet in serial application. According to industry, this may be due to the difficulty in colour mixing, making recycling impossible. The current powder coats do not meet most European manufacturers' requirements for durability and physical and chemical resistance.

#### Achieved environmental benefits

No data submitted.

#### Cross-media effects

Some health and safety considerations with the powder coatings (see Sections 0 and 0).

#### Operational data

No data submitted.

#### Applicability

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

DaimlerChrysler in the US has planned to completely coat the Jeep Wrangler with powder coats from 2004 onwards. BMW in Germany has now converted one production unit to powder coating. However, white topcoat cannot be achieved satisfactorily, and this is produced on the repair line.

**Reference literature**

[78, TWG, 2005] [110, Eurocar, 2005]

**19.5.3 Low-cost conversion concept**

This technique has been referred to in literature provided [13, DFIU and IFARE, 2002]. According to vehicle industry experts, it does not exist, while paint supply industry experts think it refers to the water-based base coat system with reduced flash-off, see Section .

**19.5.4 Increased use of pre-coated materials**

**Description**

A further development may be an increasing share of completely finished coil coating parts so that certain painting processes will no longer be performed by the car manufacturer (see Chapter 6).

**Achieved environmental benefits**

Because coil-coated materials are coated before forming (shaping) and completion of sub-assemblies (e.g. doors), the application and extraction techniques enable a lower VOC emission per m<sup>2</sup> coated than post-forming painting.

**Cross-media effects**

VOC emissions (although reduced) remain but are transferred to the production of the coil-coated materials.

**Operational data**

No data submitted.

**Applicability**

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

No data submitted.



### 19.5.5 Polyurethane (PU) paint systems

#### Description

Paint systems based on polyurethane can be already burned-in at temperatures below 100 °C. This allows the lacquer finish of both metal bodies and plastic mounted parts within a single painting process. A so-called 'in-line lacquer finish' would solve the problem of the colour adjustment between the metal body and the coloured plastic parts.

#### Achieved environmental benefits

No data submitted.

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

The wide range of PU-based paint systems is available for all layers of the paint structure, ranging from the primer to the finish coating as well as for sound absorption and underbody protection. The low burn-in temperatures allow for the use of a wide range of plastics.

#### Economics

No data submitted.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

No data submitted.

### 19.5.6 Reduction in paint layers

*Now introduced in integrated paint shops. See Section 2.4.2.3*

#### Description

A reduction in the number of paint layers is to be expected, as primers and base lacquers are united into one material applied in one paint film. Primerless systems using two-component water-based base coat are being introduced. Primerless systems reduce application steps from four to three and ovens from three to two. Base coat thickness is slightly increased to cover the underlying electrocoat and to protect it against the impact of UV radiation.

#### Achieved environmental benefits

Materials and energy are saved and at the same time the emissions from the painting process decrease.

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

No data submitted.

**Economics**

Primerless systems may lead to substantial cost savings.

**Driving force for implementation**

No data submitted.

**Example plants**

In commercial use at DaimlerChrysler Rastatt, Germany; SEAT Martorell, Spain; Mini Oxford, UK; and VW, Mexico. Further plants are scheduled for transformation.

**Reference literature**

[78, TWG, 2005].

**19.6 Coating of trucks and commercial vehicles**

No data submitted.

**19.7 Coating of buses**

No data submitted.

**19.8 Coating of trains**

No data submitted.

**19.9 Coating of agricultural and construction equipment**

No data submitted.

**19.10 Coating of ships and yachts**

**19.10.1 Hot electrostatic air mix**

**Description**

This technique can be used indoors and outdoors. Because of the heating of the paint, the right viscosity can be gained so less VOC is emitted. Note that production can be lower than with conventional techniques.

**Achieved environmental benefits**

Reduced VOC emissions.

**Cross-media effects**

No data submitted.

**Operational data**

No data submitted.

**Applicability**

Applicable indoors, for example with maintenance and repair work, and outdoors, in combination with S-shaped windscreens.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

In the Netherlands, a pilot is being carried out to use hot electrostatic air mix techniques on ships.

**Reference literature**

[38, TWG, 2004]

### **19.10.2 Replacement of antifouling paints based on biocides (substitution)**

#### **19.10.2.1 Paints with natural biocides**

**Description**

Natural biocides are produced, for example, by some coral species as a protection against fouling.

**Achieved environmental benefits**

This antifouling system does not contain heavy metals or biocides.

**Cross-media effects**

No data submitted.

**Operational data**

These substances show a lower persistence due to a better biodegradability rating compared to inorganic materials such as copper compounds or TBT.

**Applicability**

Paints containing natural biocides are still being tested.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002].

#### **19.10.2.2 Coatings with special surface properties for a reduction of fouling**

**Description**

Coatings with a special surface structure such as micro-roughness can be used for a reduction of fouling.

**Achieved environmental benefits**

This antifouling system does not contain heavy metals or biocides.

**Cross-media effects**

No data submitted.

**Operational data**

A pilot project for the testing of environmentally sound antifouling paints was carried out by an environmental regulator, a green NGO and paint manufacturers. During the study, this type of coating performed the best out of all biocide-free materials.

**Applicability**

Applicable to all ships.

**Economics**

Costs are claimed to be comparable to other tin- and copper-free antifouling systems.

**Driving force for implementation**

IED. Water pollution legislation and policies.

**Example plants**

No data submitted.

**Reference literature**

[13, DFIU and IFARE, 2002] [69, Watermann, et al., 2003] [78, TWG, 2005]

**19.11 Coating of aircraft**

No data submitted.

**19.12 Coating of other metal surfaces**

No data submitted.

**19.13 Coil coating industries**

No data submitted.

## 19.14 Coating and printing of metal packaging

### 19.14.1 Low-solvent coating (waterborne paint)

#### Description

The solvent percentage depends on the mechanical and chemical performance requirements. No further data submitted.

#### Achieved environmental benefits

No data submitted.

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

Currently, no suitable high performance water-based internal lacquers are available.

#### Economics

No data submitted.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

[38, TWG, 2004]

### 19.14.2 Radiation curing processes

#### Description

For a general description, see Section 17.8.5. No commercial application is known for coil coating applications. See also Section 6.4.4.2.

#### Achieved environmental benefits

Reduces solvent emissions.

#### Cross-media effects

No data submitted.

#### Operational data

Radiation curing may become an important technology for new lines but it is difficult to see how it could be a viable replacement for a conventional solvent-based coating as a retrofit on an existing line. In its current state of development, radiation curing cannot meet the specifications for the whole range of coil coating products. Small scale trials continue with development products. UV lamps or EB units will need to be installed on lines wishing to run radiation cured coatings. These factors mean that a changeover to radiation cured coatings is not feasible for coil coating installations at present.

#### Applicability

No data submitted.

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### **Economics**

No data submitted. **63, COM, 2003**

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

**Reference literature**[38, TWG, 2004] [22, ECCA, 2004]

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## 19.15 Serial coating of plastic workpieces

### Description

Currently, research is underway into the development of thermal curing low temperature powders and UV curing powder coatings.

### Achieved environmental benefits

No data submitted.

### Cross-media effects

No data submitted.

### Operational data

No data submitted.

### Applicability

Early results are promising for the application capability of such powder systems for some plastic parts. Water-based in mould coating systems applied to the coating of steering wheels are at a testing stage.

### Economics

No data submitted.

### Driving force for implementation

No data submitted.

### Example plants

No data submitted.

### Reference literature

[38, TWG, 2004]

## 19.16 Coating of furniture and wood materials

### 19.16.1 Power coating

#### Description

At present, research into the application of powder coatings for the woodworking industry is strongly associated with the development of new generations of powder coating materials, which have more suitable melting and curing processes. Powder coating systems cross-linking by UV radiation are still at an early stage of their development, but UV cured powders are already used in production for, e.g. MDF and flat wood panels. At present, the electrostatically assisted application of powder coatings onto non-conductive wood and wood materials is under development.

#### Achieved environmental benefits

In this context, the earthing of electric charges via freshly produced wet lacquer film has been examined. This painting principle has been used for furniture fronts and has produced the following results:

- in comparison to the low-pressure procedure (HVLV), electrostatic high rotation atomisation increases the application efficiency by approximately 35 %, and accordingly the material efficiency by approximately 30 %;
- it reduces the generation of waste (paint) by approximately 80 %.

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

So far, electrostatically assisted painting processes can only be applied in rare individual cases in wood processing. Therefore, further research is necessary.

#### Economics

No data submitted.

#### Driving force for implementation

No data submitted.

#### Example plants

No data submitted.

#### Reference literature

[13, DFIU and IFARE, 2002]

### 19.16.2 Peroxide and IR bleaching

#### Description

A new method for bleaching has been developed which combines peroxide application and infrared radiation. No further data submitted.

#### Achieved environmental benefits

No data submitted.

#### Cross-media effects

No data submitted.



**Operational data**

No data submitted.

**Applicability**

No data submitted.

**Economics**

No data submitted.

**Driving force for implementation**

No data submitted.

**Example plants**

No data submitted.

**Reference literature**

[www.altonic.fi](http://www.altonic.fi)

**19.16.2.1 Non-thermal plasma treatment****Description**

In the waste gas, a plasma is created at low temperatures (30–120 °C) by routing the waste gas through two electrodes with an alternating current of 20–30 kV. In the plasma, the VOC vapours react very quickly with oxygen to form CO<sub>2</sub> and water vapour.

In a plasma, the molecules of the gas flow are in a partly ionised condition. This condition is normally achieved by extremely high temperatures, such as that caused by lightning. However, it can also be created at ambient temperatures if enough energy is added.

**Achieved environmental benefits**

Efficiencies of 97–99.9 % are achieved without heating the waste gas. The installation for this technique is very compact compared to thermal oxidation and also consumes far less energy.

**Cross-media effects**

Energy consumption of 0.5–3.0 kWh electric energy per 1 000 m<sup>3</sup> waste gas treated.

**Operational data**

Different layouts are available. Sometimes the space between the electrodes is filled with small glass balls to amplify the electric field.

**Applicability**

This technique has only been commercially applied for a few years to reduce odour emissions and sometimes to treat waste gases containing VOC. At the moment, the technique is used as a pilot in a demonstration project applied to treat VOC emissions from the drying of wood. The technique was expected to be commercially applied to this application in 2004.

In theory, there is no restriction in applications concerning the VOC concentrations in the waste gas; however, it is currently applied for treating low concentrations. Also small or large flows can be treated.

**Economics**

No data on cost are available yet. However, this technique is expected to be cheaper than thermal oxidation or adsorption.

**Driving force for implementation**

No data submitted.

**Reference literature**

[27, VITO, 2003] [38, TWG, 2004]

**19.17 Wood preservation**

No data submitted.

**19.18 Manufacture of mirrors**

No data submitted.

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## 19.19 Waste gas treatment

### 19.19.1 Electrically heated carbon adsorption tubes

#### Description

Carbon adsorption tubes can be mounted on individual printing/coating application lines and used to adsorb VOCs. The VOCs can then be recovered by passing a current through the electrically conducting carbon tubes.

#### Achieved environmental benefits

No data submitted.

#### Cross-media effects

No data submitted.

#### Operational data

No data submitted.

#### Applicability

No data submitted.

#### Economics

No data submitted.

#### Driving force for implementation

No data submitted.

#### Example plants

Small-scale trials have been shown to be successful in the UK.

#### Reference literature

[38, TWG, 2004]

## 19.20 Waste water treatment

### 19.20.1 Wet separation spray booth – with SiO<sub>2</sub> particles

#### Description

Overspray in a spray booth where surfaces are sprayed with paint materials can be intercepted by applying a water curtain. The water-paint mixture is captured and treated in a reservoir below the spray booth. SiO<sub>2</sub> particles are added to the water reservoir and while floating at the surface are adsorbing the paint particles. When the SiO<sub>2</sub> particles are saturated with paint, they are removed from the reservoir and are recovered as a new paint.

**Achieved environmental benefits:** VOC emissions are reduced and the recovered paint and SiO<sub>2</sub> particles can be reused in a new paint.

#### Cross-media effects

Arising of waste water which can often be reused.

#### Operational data

The process is fully developed and ready for commercialisation; however, it is not yet available on a large scale.

#### Applicability

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Wet separation spray booths are common practice in wood and furniture painting and in the automotive industry. They are applicable to water- and solvent-based paints.

The technique is currently not applied on a commercial level.

### **Economics**

Not known yet.

### **Driving force for implementation**

No data submitted.

### **Example plants**

No data submitted.

### **Reference literature**

[27, VITO, 2003]

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## 20 CONCLUDING REMARKS

*To be rewritten near the conclusion of the work*

### 20.1—Timing of the work

The kick-off meeting of the Technical Working Group (TWG) was held in March 2003 and the first draft was issued for consultation in May 2004. The second draft (with BAT proposals) was issued for consultation in October 2005. The final TWG meeting was held in June 2006.

### 20.2—Sources of information and progress of the work

Eighteen industries are discussed in this document, using approximately 150 information sources. The type, quantity and quality of data varied according to the industry.

The Solvent Emissions Directive (IED) also applies to all the industries in this sector. Some reports were prepared by Member States and the industries concerned on good practice and potential BAT to assist implementation of the directives before work started on this document, and these formed the basis of the first draft. Reports from two Europe-wide studies prepared to implement the SED and UNECE Protocols controlling VOCs<sup>29</sup> were also used. Some of the documents supplied considered the industry at the much lower SED thresholds, which caused some difficulty, particularly in identifying process descriptions and techniques for the IPPC BAT discussion. However, it should be noted that the TWG has clarified these issues through the information exchange and has drawn conclusions based on the data for installations exceeding the IPPC capacities.

Good practice or BAT guides were received from the following MS: Austria, Belgium, France, Germany, the Netherlands, the Nordic Council and Spain, predominantly on printing and painting. There was little other data on consumption and emissions from MS.

The role of industry in providing data and clarifying issues was crucial. This was considerably assisted by most of the industries discussed and their suppliers and consultants participating in ESVOCCG<sup>30</sup>. Suppliers and consultants have an important overview and played a significant role in providing and clarifying data on techniques, consumption and emissions.

Major BAT studies, guidance documents, industry surveys, etc. were supplied (among others) by: printing, winding wires, adhesive tape, automotive industries, coating of ships (from Portugal), metal packaging, coil coating and mirrors. Some industries also used their own shadow TWGs to provide co-ordinated industry responses. Seven industry associations, together with ESIG, provided substantial contributions, and estimated their costs to be EUR 1.36 million (an average of EUR 191000 per association). In all, ESVOCCG estimates the total industry contribution to the information exchange to be about EUR 2.2 million.

A major source of data has been the comments from the TWG to the two drafts: nearly 2000 in each case. Further information has also been exchanged to clarify individual techniques and comments.

<sup>29</sup> Documents from DFIU/IFARE (including ISACOAT studies) prepared for the implementation of SED were used in several chapters. EGTEI data were prepared in support of the UNECE Protocols to reduce the transboundary transport of VOCs and NO<sub>x</sub>. As a result of this information exchange, some of the EGTEI documents have also been updated in consultation with the industries concerned.

<sup>30</sup> ESVOCCG: the European Solvents VOC Coordination Group co-ordinates the solvent industries' responses to the relevant European policy proposals and legislation under the auspices of CEFIC.

Information also came from site visits to installations demonstrating potential BAT for printing, packaging, manufacture of winding wires, vehicle assembly, can coating and furniture painting in France, the Netherlands and Germany. Meetings with ESVOCCG and ACEA<sup>31</sup> also contributed to the exchange.

EGTEI synopsis sheets are prepared to assist the collection of national data on emissions the RAINS model. These contain data for the cost benefit at a European level of the application of key abatement techniques in various industries, and these data have been used to check the BAT conclusions, add background information on industries, and in some cases to support the derivation of BAT. Equally, the participation of CITEPA (the authors) in the TWG also enabled the verification and updating of some of the synopsis sheets, leading to more consistency. The EGTEI approach is necessarily limited in complexity, and cannot consider all the possible techniques for BAT, and does not take into account other BAT considerations, such as cross-media effects or the technical characteristics of individual products or BAT at an installation level. The data therefore do always not map easily into the BREF format and methodology. However, the data are useful at a high level and are fully referenced in the document.

To minimise repetition, as many techniques as possible that could be considered for use by more than one industry were discussed generally in Chapter 20. A major section of this is on waste gas treatment, and a sub group meeting was held to facilitate the drafting of this and reaching BAT conclusions. Because so many different processes and combinations of techniques were being discussed, each with their own variability, it was agreed that the focus of the BAT conclusions should be to find emission ranges associated with suitable combinations of the best available techniques. It was also agreed that these ranges should be based on meaningful production related measures for each industry, such as VOC emitted in g/m<sup>2</sup> treated or per kg of solids input. These emission ranges are usually the same as those used for the SED implementation, to reduce confusion.

Many of the data were focused predominantly on VOC emissions and there was a significant lack of data on other issues for integrated process control and reduction of consumption. In common with other BREF projects, there was a lack of quantitative data in many areas.

Data received on the magnetic tape industry showed that there were only three installations in the EU, and one of these had 80 % of the European market. On the basis that this industry is being replaced by other types of recording data, an information exchange was not considered to be resource effective. Information received on the shoe manufacturing industry showed that none in the EU reached the IPPC thresholds. For friction linings, less than 10 German companies account for half the European production, with only about 20 % of production using solvent based processes. Again, an information exchange was not considered to be resource effective. Both of these processes should be considered for the first review.

No data were received on the manufacture of boats using polyester resins, so it remains unclear if this activity is within the scope of this document.

It is reported that some installations processing semi conductors and some printing of wallpapers may use solvents for degreasing above the IPPC thresholds, but no data were received.

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<sup>31</sup> ACEA: the European association of automotive manufacturers.

## 20.3 Degree of consensus

Industry asked for clarification of the definitions of 'organic solvents' and 'consumption capacity' in Annex 1 (6.7) to the IPPC Directive. At the conclusion of the information exchange, it could be seen that the exchange had dealt with information on organic solvents being defined as VOCs (as defined in the Solvent Emissions Directive, Council Directive 1999/13/EC). It could equally be seen that, in determining conclusions on BAT, the exchange had focused on installations whose actual use of solvents exceeded the consumption capacity thresholds stated in the IPPC Directive (where the use in the activity included solvents recovered from waste gas emission abatement equipment). Interpretation of these capacity thresholds is discussed in the context of work carried out by DG Environment to develop some guidance on the interpretation of certain provisions of the Directive.

A high level of consensus was achieved overall on the techniques to be considered and the BAT conclusions, with one split view requested by industry.

## 20.4 Gaps in knowledge and recommendations for future research and information gathering

The following gaps in knowledge were identified as a consequence of the information exchange. Some are described in the main text, others under development are described in Chapter 22, Emerging Techniques. They are summarised here with proposals for future work:

### 20.4.1 General issues:

**Industries considered.** As noted above, this document does not discuss the manufacture of magnetic tapes, self-adhesive labels, friction linings, boat construction using resins, semi-conductors and wallpapers.

**Recommendation:** Data should be gathered on these industries to assess if they should be considered for inclusion in the review of this document.

**EGTEI synopsis sheets.** As noted in Section 20.2, above, these have provided helpful data. However, the approach often does not map readily into the BREF format and methodology.

**Recommendation:** Maintain liaison with CITEPA/EGTEI and consider using EGTEI data to a greater extent particularly for any update or review. Also, ensure CITEPA/EGTEI are aware of developments in BAT.

**Energy usage.** This is probably the next most important issue in this sector after VOC emissions. However, for process techniques, it has been almost impossible (there are a few exceptions) to derive BAT or consumption values related to production for energy.

**Recommendation:** More data are required on the energy usage associated with techniques, and related to production throughput measures. These would be most helpful if they are related to the same production measures used for VOC emissions.

**Energy used in EoP techniques and quantifying the cross-media and economic effects of abatement.** Attempts have been made to quantify these issues, but insufficient data were available (see specifically the metal packaging industry, below). One option is comparing marginal social costs of burning natural gas to abate VOCs, particularly at low concentrations, but available costs have been prepared on different bases and the costs have uncertainties attached to them (particularly those for CO<sub>2</sub>).

**Recommendation:** More information is required to help determine the selection of investment routes (cost benefit of abatement verses more efficient application and low solvent techniques) and to determine when it is possible to turn off waste gas treatments when low solvent substitutions have been made (see the metal packaging sector for more detail).

**Using less hazardous substances: using solvents with lower ozone formation potential (OFP).** No discussion on VOC emissions would be complete without a discussion of ozone formation and the differing potentials of the various solvents to form ozone. The technique is referred to in the ECM REF, and the STS TWG exchanged important and helpful information. The conclusion was the technique can only be currently considered BAT in limited circumstances for several reasons:

- it is not necessary where adequate waste gas abatement exists
- there are several comparative scales (all derived by complex models). The most commonly referred to in Europe is POCP, which lists some 130 substances (not all of them solvents) and this is used in modelling for EU and MS policy requirements rather than in practical applications, such as informing process development
- these scales cannot currently be used to show compliance with legislation such as SED, although substitution on this basis would assist meeting the objectives of the SED and IPPCD
- OFP scales are not used when deriving complex formulations such as paints and inks. The costs of applying this and deriving new formulations are high and the time scales long, so using them as a basis for substitution in these mixtures is not currently feasible. This would be better achieved as part of other exercises, particularly under REACH, where the issue can be considered as one of several factors, and development costs can be shared.

While controlling the emission of VOCs will assist in controlling ozone formation, the anticipated benefits will not be achieved if the total ozone formation load (mass released x OFP) remains higher than anticipated. As an example, one of the widely applicable BAT options is the use of high solids paints. However, during the final TWG meeting it was noted that to achieve the required dispersion of the pigments, more powerful solvents are used. These may be from types of solvent with significantly higher ozone forming potentials, so while the VOC emission may be significantly reduced, the expected reduction in ozone formation may not be realised.

**Recommendation:** More research and information is therefore required to:

- assess the use of the OFP worldwide in regulation
- ensure that the most appropriate OFP scale and/or the most suitable scale is developed for future EU initiatives use, e.g. to give data on a wide range of commonly used solvents, and to aid development as an emissions control technique
- assist the development and application of this technique in paints, inks and other surface treatments containing VOC, e.g. under REACH
- assess the impact of paints and surface treatments recently developed as substitutes to meet SED requirements and determine their effectiveness in reducing the EU, MS and local burdens of ozone.

**NO<sub>x</sub> from solvents containing nitrogen.** These are used in some of the processes discussed. It is unclear to what extent oxidation of these is a major source of NO<sub>x</sub>, and if this will change in the future, as other initiatives are likely to lead to a decline in the use at least one solvent containing nitrogen

**Recommendation:** More information is needed on the amount of solvents containing nitrogen used in the EU, and projected future usage and to calculate the amount of NO<sub>x</sub> these solvents contribute to the EU and local burdens.

**The use of high efficiency application techniques.** Although these are often given as BAT, or are included in a group of techniques to consider to achieve emissions associated with BAT, they are often not recognised as having an effect on VOC emissions if these are calculated, for example, as kg VOCs/kg solids input. In these cases, both VOC and solids used are reduced, and the kg/kg ratio remains the same. This may prevent the more rapid application of BAT in some industries, and would include minimising raw material consumption. Decreased VOC



emissions are shown where calculated against a production output parameter, such as VOC g/m<sup>2</sup>.

**Recommendation:** More data are required on the applicability of these techniques in some industries, and more guidance is required on how to calculate the VOC emissions.

**The use of novel techniques in waste gas treatment.** There was little information available on more recent, non-traditional techniques to treat waste gases which might be able to reduce capital investment, reduce energy consumption and/or running costs, such as UV oxidation, non-thermal plasma, and carbon absorption tubes mounted in individual treatment lines (an emerging technique). The lack of information may be due to poor take up, in turn caused by the lack of information to base investment decisions on. There was also contradictory information on biological treatment, with both reported successes and failures, which require further clarification of the applicability of this technique.

**Recommendation:** Seek further information on these and other possible techniques, cost-effectiveness and cross-media effects, and support research into the development of alternative waste gas treatment techniques.

**Novel technique for materials recovery in spray booths.** Overspray in paint booths is frequently intercepted by water curtains. An emerging technique is described using SiO<sub>2</sub> particles to enable the paint to be recovered, but little information was supplied.

**Recommendation:** Seek further information on these and other possible techniques, cost-effectiveness and cross-media effects, and support research into the development of alternative material recovery techniques.

**Secondary aerosols.** These were identified at the final TWG plenary meeting as an emission that had not been discussed during the information exchange.

**Recommendation:** More information is required to determine if and in which processes this may be an environmental problem. If a problem is identified, then information on the extent and its control will be required.

## 20.4.2 — Industry-specific issues

**Flexographic printing:** Some beverage cartons are printed using solvent free UV curing flexographic inks. These use UV curing inks which could be developed for other applications.

**Recommendation:** Research to support the wider application of solvent free UV inks and other surface treatments.

**Publication gravure printing:** A considerable amount of energy is used in regenerating adsorption beds used to control toluene emissions. To remove the maximum amount of toluene involves increasing the absorption cycles and therefore energy. The toluene emission level at which the energy consumption starts to climb exponentially is not known and requires a series of trials.

**Recommendation:** A series of trials is needed to derive data establishing the toluene emission as a percentage of the total toluene input with the minimum optimum energy usage. The trials can be carried out in existing installations.

**Winding wires:** The remaining area of significant VOC emission is from the application of lubricants. The industry provided data demonstrating that it was not economically or technically viable to enclose and treat the air required to evaporate the solvent from the lubricant. Developments in BAT have centred on the use of solvent free lubricants, but these are limited by (i) wire size, and (ii) these lubricants not meeting all customer specifications.

**Recommendations:** Research is required to develop further solvent free lubricant systems that meet the necessary performance requirements, and to assist with the gaining of the performance specifications for existing options.

**Abrasives:** Emerging techniques for faster drying and hardening of the bonding materials have been identified, for example, using UV or microwave radiation and probably low or no solvent.

**Recommendation:** More information is required on these techniques.

**Coating of cars, vans, trucks and truck cabs, and buses:** There was less information available on commercial vehicles and buses than for cars. Energy was identified as a major concern, but there is difficulty in establishing comparable data, even within the same company.

The following are in development and may contribute to future BAT:

- improved water based 1 and 2 component clear coating
- very high solids clear paints (up to 90 % solids)
- increased use of pre-coated materials, reducing the painting in the assembly installation. Because coil-coated materials are coated before forming (shaping) or assembly, the application and extraction techniques enable a lower VOC emission per m<sup>2</sup> coated than post forming painting
- powder coating is used in the US and one or two plants in the EU. It is not widely used in Europe, as it does not meet manufacturers quality specification for chemical and physical durability
- low cost conversion concept (LCCC). This technique has been described and reference plants identified, but there seems to be doubt about its definition (i.e. is the naming and description wrong) and/or existence. Typical water based base coat systems used to achieve low emission levels need high capital investment. The LCCC is claimed to use paints with similar characteristics, but use less energy and require less equipment change and less capital investment. Supply industry information was given on water based coatings with reduced flash-off requirement, which is in commercial use in at least two plants, and this is described
- polyurethane (PU) paint systems enable both metal bodies and plastic parts to be painted together in a single process. It is unclear what the effect this will have on VOC emissions, although lower oven temperatures are likely to save energy
- reduction in paint layers as primers and base coats are merged, such as by using two component water based base coats, resulting in reduced emissions of VOC, waste and waste water and a reduction in energy consumption.

**Recommendation:** More information is required on the status of these techniques, their cross-media effects, applicability and economics. Powder coating can achieve low VOC emission levels, but more research is required to improve the quality of the finishes to European manufacturers' standards. More data are required on the LCCC concept, to clarify the terminology, and the technique and its benefits.

**Coating of trains, agricultural and construction equipment, ships and yachts, aircraft, other metal surfaces, plastics:** Very little information was received on these topics, although significant additional information was provided after Draft 2 for ship repair. Conclusions were drawn for other metal surfaces and plastics based on the automotive (OEM) installations and the expert opinion of the TWG.

**Recommendation:** More data are required in these areas to improve the quality of the BAT conclusions. Data on the manufacturing and coating of new ships and yachts (particularly using polyester resins) are needed. The shipping industry (and others) may not understand that high solids paints (with lower solvent emissions) may be more expensive per kg, but the same price per m<sup>2</sup> treated: more information needs to be made available on this.

**Metal packaging:** There is little information on the application of some potential BAT (low solvent or solvent free water based coatings) as their application in the industry is hindered. To deal with the original higher solvent concentration techniques, large waste gas oxidisers are installed, which deal with high volumes of air, and can be 25 % of the site capitalisation. As solvent emissions are reduced, the solvent concentration in the air stream drops well below the autothermal level, requiring gas as a fuel. No data exist on when to turn off these oxidisers. It is not economically viable to both convert to low solvent or solvent free coatings and use gas to support combustion of the low level of remaining solvent.

**Recommendation:** More information is required on when to turn off EoP techniques (see Energy used in EoP techniques, above).

**Coil coating:** Radiation curing is used in other industries in conjunction with low solvent or solvent free coatings. Development work has been undertaken for its application in coil coating.

**Recommendation:** More information is required on the status and applicability of radiation curing process. Research may be needed to assist its applicability to existing plants.

**Furniture and wood coating:** There was limited information on waste gas treatments, especially on the potential to use thermal oxidisers in high solvent applications. Powder coatings (with UV curing) and electrostatic high rotation application have been developed with some success for large flat panels.

**Recommendation:** More research is required to develop these and similar techniques to a wider range of products to reduce solvent usage.

### **RTD programme**

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future document reviews. Readers are therefore invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the preface to this document).

## **20.5 Review of this document**

The data on techniques relating to VOC usage and emissions is largely current to the information exchange (2003 to 2006), and unlikely to change until more experience has been acquired in confirming with, regulating for and reporting for the SED and IPPCD. This additional data would also assist with considering the industries not discussed in this document (identified in Section 20.2). The lack of data on other issues (identified in Section 20.4) needs addressing, but this would also benefit from the studies proposed and experience gained in applying the directives. End of pipe abatement techniques are predominantly mature, and other techniques such as substitution develop gradually. National documents covering these industries show little need for change seven years after the introduction of the SED. A review may be considered for approximately 2009 to address gaps in data, particularly for the industries that may potentially be within the scope of this document, although it is unlikely that a full review will need to be considered before 2012.

An issue for consideration will be how to update the document if fresh information is available for a minority of the techniques and industries earlier than 2012.

## 21 ANNEXES

### 21.1 List of plants participating at the STS data collection

Code number	Main sector	Member state	Proposed by:	Installation / Site / Line name	Company name	Town
001	Heatset offset printing	ES	ES	Altair	Altair	Seseña (Toledo)
002	Heatset offset printing	ES	ES	ROTOCOBRHI SAU	ROTOCOBRHI SAU	Tres Santos - Madrid
003	Heatset offset printing	IT	IT	COPTIP INDUSTRIE GRAFICHE SOC. COOP. A R.L.	COPTIP INDUSTRIE GRAFICHE SOC. COOP. A R.L.	Modena (MO)
004	Heatset offset printing	PT	PT	Lidergraf	Lidergraf	Vila do Conde
005	Flexography and packaging gravure	AT	AT	Jodl Verpackungen GmbH	Jodl Verpackungen GmbH	Lenzing
006	Flexography and packaging gravure	AT	AT	TANN Papier GmbH	TANN Papier GmbH	Traun
007	Flexography and packaging gravure	AT	AT	PAWAG Verpackungen GmbH	PAWAG Verpackungen GmbH	Wolfurt
008	Flexography and packaging gravure	AT	AT	Lenzing Plastics GmbH	Lenzing Plastics GmbH	Lenzing
009	Flexography and packaging gravure	AT	FPE	Constantia Teich Austria	Constantia Teich Austria	Mühlhofen
010	Flexography and packaging gravure	AT	Mondi	Mondi	Mondi	Korneuburg
011	Flexography and packaging gravure	BE	BE	Chiyoda Europe Genk	Chiyoda Europe	Genk
012	Flexography and packaging gravure	DE	FPE	Constantia Hueck Weiden	Hueck	Pirkmühle
013	Flexography and packaging gravure	DE	DE	Constantia-HuN-Hann-Muenden	Haendler & Natermann GmbH	Hann Munden
014	Flexography and packaging gravure	DE	DE	Rahning GmbH & Co. KG	Rahning GmbH & Co. KG	Bunde
015	Flexography and packaging gravure	DE	AMCOR	AF Rinteln	Amcors Flexibles	Rinteln
016	Flexography and packaging gravure	DK	DK	Danapak Flexibles A/S	Danapak Flexibles A/S	DK-4200 Slagelse
017	Flexography and packaging gravure	EL	EL	Komotini's Factory	ALFA BETA ROTO SA (VAT Nr: EL	Komotini, Thrace

Code number	Main sector	Member state	Proposed by:	Installation / Site / Line name	Company name	Town
					094470520)	
018	Flexography and packaging gravure	ES	ES	ENPLATER	Envases Plásticos del Ter, sa	Torroella de Montgrí
019	Flexography and packaging gravure	FR	FR	Amcors Tobacco Packaging France SAS	AMCOR	UNGERSHEIM
020	Flexography and packaging gravure	IT	IT	Goglio Daverio	Goglio S.p.A.	Daverio (VA)
021	Flexography and packaging gravure	IT	IT	Gruppo Fabbri Vignola S.P.A.	Gruppo Fabbri Vignola S.P.A.	Vignola (MO)
022	Flexography and packaging gravure	IT	IT	Safta S.p.A.	Gualapack Group	Piacenza
023	Flexography and packaging gravure	IT	IT	Centroplast SpA	Centroplast SpA	Meldola (FC)
024	Flexography and packaging gravure	IT	IT	Flexible, printed, laminated and cut packagings' production plant	Sidac S.p.A.	Forlì
025	Flexography and packaging gravure	IT	AMCOR	AF Lugo	Amcors Flexibles	Lugo di Vicenza
026	Flexography and packaging gravure	NL	NL	FLEXOPLAST BV	FLEXOPLAST BV	Harligen
027	Flexography and packaging gravure	PL	PL	EMSUR POLSKA SP. Z.O.O.	EMSUR POLSKA SP. Z.O.O.	JÓZEFÓW
028	Flexography and packaging gravure	PL	FPE	Constantia Teich Poland	Teich Poland	Rogoviec
030	Publication gravure printing	FI	ERA	Helprint Oy	Circleprinters	Mikkeli
031	Publication gravure printing	UK	ERA	Bertelsmann Printing Group	Prinovis UK	Liverpool
032	Winding wires manufacturing	AT	AT	Asta Elektrodraht GmbH & Co KG	Asta Elektrodraht GmbH & Co KG	Oed
033	Winding wires manufacturing	DE	EWVG	Schwering & Hasse Elektrodraht	Schwering & Hasse	Lügde
034	Winding wires manufacturing	DE	EWVG	ESSEX Germany GmbH	ESSEX Germany GmbH	Engter Str. 34, 49565 Bramsche
035	Winding wires manufacturing	SE	SE	Dahrentrad	Dahrentrad	Jonslund
036	Manufacturing of adhesive tape	AT	AT	Müroll Papier und Kunststoffverarbeitung GmbH_LINE_1	Müroll Papier und Kunststoffverarbeitung GmbH	Frastanz

Code number	Main sector	Member state	Proposed by:	Installation / Site / Line name	Company name	Town
038	Coating of passenger cars	AT	AT	Magna Steyr Fahrzeugtechnik AG	Magna Steyr Fahrzeugtechnik AG	Graz
039	Coating of passenger cars	BE	BE	Volvo Cars Gent	Volvo Cars Gent	Gent
040	Coating of passenger cars	BE	ACEA	Audi Brussels	VWAG - Audi	Brussels
041	Coating of passenger cars	CZ	CZ	Hyundai Manufacturing Czech s.r.o.	Hyundai Manufacturing Czech s.r.o.	Nižní lhoty
042	Coating of passenger cars	CZ	CZ	Paint shop of the SKODA plant Mladá Boleslav	ŠKODA AUTO a.s.	Mladá Boleslav
043	Coating of passenger cars	CZ	CZ	Paint shop of the SKODA plant Kvasiny	ŠKODA AUTO a.s.	Kvasiny
044	Coating of passenger cars	CZ	CZ	TOYOTA PEUGEOT CITROEN AUTOMOBILE Czech, s.r.o.	TOYOTA PEUGEOT CITROEN AUTOMOBILE Czech, s.r.o.	Kolín
045	Coating of passenger cars	DE	ACEA	VWAG - VW Emden	VWAG - VW	Emden
046	Coating of passenger cars	DE	ACEA	VWAG - VW Hannover	VWAG - VW	Hannover
047	Coating of passenger cars	DE	ACEA	VWAG Leipzig	VWAG - Porsche	Leipzig
048	Coating of passenger cars	DE	ACEA	BMW Regensburg	BMW GROUP	Regensburg
049	Coating of passenger cars	DE	ACEA	GENERAL MOTORS EUROPE Rüsselsheim	GENERAL MOTORS EUROPE	Rüsselsheim
050	Coating of passenger cars	DE	ACEA	DAIMLER AG Sindelfingen	DAIMLER AG	Sindelfingen
051	Coating of passenger cars	ES	ES - ACEA	PSA PEUGEOT CITROEN Madrid	PSA PEUGEOT CITROEN	Madrid
052	Coating of passenger cars	ES	ES - ACEA	PSA PEUGEOT CITROEN Vigo	PSA PEUGEOT CITROEN	Vigo
053	Coating of passenger cars	ES	ES - ACEA	RENAULT VALLADOLID Montaje	RENAULT	VALLADOLID
054	Coating of passenger cars	ES	ES	Volkswagen Navarra, S.A.U.	Volkswagen Navarra, S.A.U.	Arazuri
055	Coating of passenger cars	ES	ES - ACEA	RENAULT PALENCIA	RENAULT	Villamuriel de Cerrato (PALENCIA)
056	Coating of passenger cars	ES	ES	Zaragoza Opel plant	GM Spain	Zaragoza
057	Coating of passenger cars	ES	ES	SEAT Martorell	SEAT,S.A	Martorell

Code number	Main sector	Member state	Proposed by:	Installation / Site / Line name	Company name	Town
058	Coating of passenger cars	FR	FR - ACEA	Rennes / Chartres de Bretagne	PSA PEUGEOT CITROEN	Rennes / Chartres de Bretagne
059	Coating of passenger cars	IT	IT - ACEA	FCA Melfi Plant	FCA Melfi S.p.A.	Melfi (PZ)
060	Coating of passenger cars	PL	PL	Volkswagen Poznań Sp. z o.o.	Volkswagen Poznań Sp. z o.o.	Poznań
061	Coating of passenger cars	PT	PT - ACEA	Volkswagen Autoeuropa	Volkswagen Autoeuropa	Palmela
062	Coating of passenger cars	RO	ACEA	FORD OF EUROPE Craiova	FORD OF EUROPE	Craiova
063	Coating of passenger cars	RO	ACEA	RENAULT SA Mioveni	RENAULT SA	Mioveni
064	Coating of passenger cars	UK	UK - ACEA	General Motors Europe Ellesmere Port	General Motors Europe	Ellesmere Port
065	Coating of passenger cars	UK	UK - ACEA	Nissan Sunderland	Nissan Motor Company	Sunderland
066	Coating of vans, trucks, and truck cabs	AT	AT	MAN Truck & Bus Österreich AG	MAN Truck & Bus Österreich AG	Steyr
067	Coating of vans, trucks, and truck cabs	DE	ACEA	DAIMLER AG Düsseldorf	DAIMLER AG	Düsseldorf
068	Coating of vans, trucks, and truck cabs	DE	ACEA	DAIMLER AG Wörth	DAIMLER AG	Wörth
069	Coating of vans, trucks, and truck cabs	FR	FR - ACEA	RENAULT SOVAB	RENAULT	BATILLY
070	Coating of vans, trucks, and truck cabs	IT	IT - ACEA	SEVEL S.p.A. Atessa Plant	SEVEL S.p.A.	Atessa (CH)
071	Coating of vans, trucks, and truck cabs	IT	IT - ACEA	IVECO Suzzara	CNH Industrial	Suzzara (MN)
072	Coating of buses	DE	ACEA	DAIMLER AG Neu-Ulm	DAIMLER AG	Neu-Ulm
073	Coating of agricultural and construction equipment	UK	UK	JCB World Headquarters	JC Bamford Excavators Limited	Rocester
074	Coating of ships and yachts	FI	FI	Arctech Helsinki Shipyard Oy Yard	Arctech Helsinki Shipyard Oy	Helsinki
075	Coating of ships and yachts	PT	PT	Mitrena Shipyard	Lisnave - Estaleiros Navais, SA	Setúbal
076	Coating of ships and yachts	UK	UK	A&P Falmouth Ltd	A&P Falmouth Ltd	Falmouth
077	Coating of aircraft	DE	AIRBUS	Airbus Hamburg-Finkenwerder	Airbus Operations GmbH	Hamburg

Code number	Main sector	Member state	Proposed by:	Installation / Site / Line name	Company name	Town
078	Coating of aircraft	UK	AIRBUS	Airbus Operations Ltd Broughton	Airbus Operations Ltd	Broughton
079	Coating of other metal surfaces	DE	ECCA/EUROFER	thyssenkrupp Rasselstein GmbH TLA2 - a coating line for tinplate sheets	thyssenkrupp Rasselstein GmbH	Koblenzer Straße 141, 56626 Andernach
080	Coating of other metal surfaces	DE	ECCA/EUROFER	thyssenkrupp Steel Europe AG Coating Line for Heavy Plates (Entzunderungs- und Farbspritzanlage - EFA Hüttenheim)	thyssenkrupp Steel Europe AG	Mannesmannstraße 101, 47259 Duisburg
081	Coil coating industries	AT	AT - ECCA/EUROFER	Voestalpine Stahl GmbH line 1 Linz	Voestalpine Stahl GmbH	Linz
082	Coil coating industries	AT	AT - ECCA/EUROFER	Voestalpine Stahl GmbH line 2 Linz	Voestalpine Stahl GmbH	Linz
083	Coil coating industries	BE	BE - ECCA/EUROFER	Arcelor Mittal Belgium Geel	Arcelor Mittal Belgium	Geel
084	Coil coating industries	BE	BE - ECCA/EUROFER	Arcelormittal Belgium Gent	Arcelormittal Belgium	Gent
085	Coil coating industries	DE	ECCA/EUROFER	BBA-2 Duisburg-Beeckerwerth	ThyssenKrupp Steel	Duisburg-Beeckerwerth
086	Coil coating industries	DE	ECCA/EUROFER	EBA2 Beeckererth - Duisburg	ThyssenKrupp Steel	Duisburg-Beeckerwerth
087	Coil coating industries	DE	ECCA/EUROFER	Kreuztal BBA3	ThyssenKrupp Steel	Kreuzfal-Eichen
088	Coil coating industries	DE	ECCA/EUROFER	Ferdirf - Duisburg BBA4	ThyssenKrupp Steel	Duisburg
089	Coil coating industries	DE	ECCA/EUROFER	Bochum BNO	ThyssenKrupp Steel	Bochum
090	Coil coating industries	DE	ECCA/EUROFER	Salzgitter	Salzgitter Flachstahl GmbH	Salzgitter
091	Coil coating industries	DE	DE	thyssenkrupp Rasselstein GmbH BEA - coating and laminating line for tinplate coils	thyssenkrupp Rasselstein GmbH	Koblenzer Straße 141, 56626 Andernach
092	Coil coating industries	EL	EL - ECCA/EUROFER	Elval Oinofyta plant	Elval SA	Oinofyta
093	Coil coating industries	EL	EL - ECCA/EUROFER	VEPAL Thiva Plant	VEPAL SA	Thiva
094	Coil coating industries	FI	FI - ECCA/EUROFER	SSAB Europe Oy Hämeenlinna Coil Coating line	SSAB	Hämeenlinna



Code number	Main sector	Member state	Proposed by:	Installation / Site / Line name	Company name	Town
095	Coil coating industries	FI	FI - ECCA/EU ROFER	SSAB Europe Oy Kankaanpää Coil Coating line	SSAB	Kankaanpää
096	Coil coating industries	FR	FR - ECCA/EU ROFER	Arconic ALCOA Arconic ALCOA	Arconic ALCOA	Merxheim
097	Coil coating industries	FR	FR - ECCA/EU ROFER	ArcelorMittal Montataire	ArcelorMittal	Montataire
098	Coil coating industries	IT	IT - ECCA/EU ROFER	Marcegaglia Carbon Steel S.p.A. Ravenna	Marcegaglia Carbon Steel S.p.A.	Ravenna
099	Coil coating industries	IT	ECCA/EU ROFER	ArcelorMittal Piombino	ArcelorMittal	Piombino
100	Coil coating industries	NL	ECCA/EU ROFER	Euramax SPL Roermond	Euramax	SPL Roermond
101	Coil coating industries	NL	ECCA/EU ROFER	Hunter Douglas Europe Rotterdam	Hunter Douglas Europe	Rotterdam
102	Coil coating industries	NL	ECCA/EU ROFER	Tata Steel IJmuiden	Tata Steel	IJmuiden
103	Coil coating industries	PL	PL - ECCA/EU ROFER	ArcelorMittal Poland S.A. Organic coating line 1	ArcelorMittal Poland S.A.	Świętochłowice
104	Coil coating industries	PL	PL - ECCA/EU ROFER	ArcelorMittal Poland S.A. Organic coating line 2	ArcelorMittal Poland S.A.	Świętochłowice
105	Coil coating industries	SK	ECCA/EU ROFER	U.S. Steel Košice	U.S. Steel	Košice
106	Coil coating industries	UK	UK - ECCA/EU ROFER	Tata Steel Deeside, Flintshire	Tata Steel	Deeside, Flintshire
108	Coating and printing of metal packaging	CZ	CZ	Ardagh Skřivany	Ardagh Metal Packaging Czech Republic s.r.o.	Skřivany
109	Coating and printing of metal packaging	CZ	CZ	ALLTUB CEBTRAL EUROPE Kolin	ALLTUB CEBTRAL EUROPE	Kolin
110	Coating and printing of metal packaging	DE	EMPAC	Ardagh Metal Packaging - Erfstadt	Ardagh	Erfstadt
111	Coating and printing of metal packaging	DK	DK	Glud & Marstrand A/S Hedensted	Glud & Marstrand A/S	Dk-8722 Hedensted
112	Coating and printing of metal packaging	DK	DK - EMPAC	Glud & Marstrand A/S Odense	Glud & Marstrand A/S	Dk-5000 Odense C
113	Coating and printing of metal packaging	FR	FR - EMPAC	Ardagh - La flèche	Ardagh - La flèche	La flèche
114	Coating and printing of metal packaging	FR	FR - EMPAC	Crown - Custines	Crown - Custines	Custines

Code number	Main sector	Member state	Proposed by:	Installation / Site / Line name	Company name	Town
115	Coating and printing of metal packaging	FR	FR - EMPAC	Crown Emballage France Crown - Nantes	Crown Emballage France Crown - Nantes	Nantes
116	Coating and printing of metal packaging	IT	IT	CROWN AEROSOLS ITALIA S.R.L.	CROWN AEROSOLS ITALIA S.R.L.	Spilamberto (MO)
117	Coating and printing of metal packaging	SE	SE	Ball Beverage Packaging Fosie AB	Ball Beverage Packaging Fosie AB	Malmö
118	Coating and printing of metal packaging	UK	UK	Botcherby	CROWN Packaging UK plc	Carlisle
119	Coating and printing of metal packaging	UK	UK	Braunstone	CROWN Packaging UK plc	Leicester
120	Coating and printing of metal packaging	UK	UK	Sutton-in-Ashfield	CROWN Aerosols UK Ltd	Sutton-in-Ashfield
121	Coating and printing of metal packaging	UK	UK	Ardagh Metal Packaging Norwich	Ardagh Metal Packaging	Norwich
122	Coating and printing of metal packaging	UK	UK	L11 & L17 Scunthorpe	Can Pack UK	Scunthorpe
123	Coating and printing of metal packaging	UK	UK	Ardagh group Wrexham	Ardagh Group	Wrexham
124	Coating and printing of metal packaging	UK	UK	Ardagh group Rugby	Ardagh Group	Rugby
125	Coating and printing of metal packaging	UK	UK	Ball Beverage Packaging Europe - Milton Keynes	Ball Bevergae Packaging Europe BBP	Milton Keynes
126	Coating of plastic work pieces	BE	BE	Plastal Gent	Plastal	Gent
127	Flexography and packaging gravure	CZ	CZ	FATRA, a.s. Napajedla	FATRA, a.s.	Napajedla
128	Coating of plastic work pieces	CZ	CZ	Automotive Lighting s.r.o. Jihlava	Automotive Lighting s.r.o.	Jihlava
129	Coating of plastic work pieces	CZ	CZ	PLAKOR CZECH s.r.o.	PLAKOR CZECH s.r.o.	Ostrava
130	Coating of plastic work pieces	CZ	CZ	Magna Exteriors (Bohemia) s.r.o. Librec	Magna Exteriors (Bohemia) s.r.o.	Librec
131	Coating of plastic work pieces	IT	IT	Stabilimento V2 Vulcaflex SpA	Vulcaflex SpA	Cotignola (RA)
132	Coating of plastic work pieces	SE	SE	Plastal Arendal	Plastal Industri AB	Göteborg
133	Flexography and packaging gravure	BE	BE	AMCOR FLEXIBLES TRANSPAC GENT BVBA	AMCOR FLEXIBLES TRANSPAC GENT BVBA	GENT

Code number	Main sector	Member state	Proposed by:	Installation / Site / Line name	Company name	Town
134	Coating of textiles, foils and paper	BE	BE	Sioen Ardoorie	Sioen Fabrics SA	Ardoorie
135	Coating of textiles, foils and paper	BE	BE	Sioen Mouscron	Sioen Fabrics SA	7700 Mouscron
136	Coating of textiles, foils and paper	BE	BE	Vetex Ingelmunster	Vetex	Ingelmunster
137	Coating of textiles, foils and paper	DE	DE	EUROFOIL BERLIN	EUROFOIL	BERLIN
138	Coating of textiles, foils and paper	PL	PL	Sanwil Polska sp z o.o. Przemyśl	Sanwil Polska sp z o.o.	Przemyśl
139	Coating of textiles, foils and paper	UK	UK	Wrexham Facility	Coveris Advanced Coatings	Wrexham
140	Coating of textiles, foils and paper	UK	UK	Dartex Coatings Long Eaton	Dartex Coatings	Long Eaton
141	Coating of furniture and wood materials	SE	SE	IKEA and SE TWG members	IKEA Industry Älmhult AB	Älmhult
142	Winding wires manufacturing	other	EWVG	CH - ELECTRISOLA FEINDRAHT	CH - ELECTRISOLA FEINDRAHT	
143	Publication gravure printing	FR	FR	BurdaDruck France Thann	BurdaDruck France	THANN
144	Coil coating industries	DE	DE - ECCA	Novelis Deutschland GmbH	Novelis Deutschland GmbH	Göttingen
145	Coating of aircraft	FR	AIRBUS	Airbus Toulouse	Airbus Operations France	Toulouse
146	Coating of passenger cars	FR	FR	Renault Douai	Renault Douai	Douai
147	Coating of vans, trucks, and truck cabs	FR	FR	Renault Maubeuge	Renault Maubeuge	Maubeuge
148	Heatset offset printing	DE	DE	GD Gotha Druck und Verpackung GmbH & Co. KG	GD Gotha Druck und Verpackung GmbH & Co. KG	Günthersleben-Wechmar
149	Publication gravure printing	DE	DE	Burda Druck GmbH	Burda Druck GmbH	Offenburg
150	Heatset offset printing	DE	DE	WKS-Kraft-Schloetels_Essen	WKS-Kraft-Schloetels	Wassenberg
151	Coating of textiles, foils and paper	DE	DE	BSN medical GmbH	BSN medical GmbH	Hamburg
152	Coil coating industries	FR	FR	Tata Steel Maubuge	Tata Steel	Maubeuge
153	Coil coating industries	FR	FR	NLMK STRASBOURG	NLMK STRASBOURG	Strasbourg

Code number	Main sector	Member state	Proposed by:	Installation / Site / Line name	Company name	Town
154	Heatset offset printing	DE	DE	Niedermayer_Regensburg	Franz Anton Niedermayr Graphische Kunstanstalt GmbH & Co.KG	Niedermayer_Regensburg
155	Flexography and packaging gravure	DE	DE	Bischof+Klein_Lengerich	Bischof+Klein_Lengerich	Lengerich
156	Manufacturing of adhesive tape	DE	DE	TESA Hamburg	tWHH tesa Werk Hamburg GmbH	Hamburg
157	Flexography and packaging gravure	DE	DE	Mondi Halle	Mondi Halle GmbH	Halle in Westfalen
158	Coil coating industries	DE	DE	Huehoco	Huehoco	Wuppertal
159	Flexography and packaging gravure	DE	DE	Debatin Bruchsal	Anton Debatin GmbH	Bruchsal
160	Winding wires manufacturing	ES	EWVG	EDERFIL BECKER, Koop. E. (LEGORRETA)	EDERFIL BECKER, KOOP.E.	LEGORRETA
161	Flexography and packaging gravure	FR	FR	Amcors Flexibles Montreuil-Bellay	Amcors Flexibles Montreuil-Bellay	Montreuil-Bellay
162	Heatset offset printing	DE	DE	NEEF + STUMME premium printing GmbH & Co. KG	NEEF + STUMME premium printing GmbH & Co. KG	Wittingen
163	Manufacturing of adhesive tape	DE	DE	monta Klebebandwerk GmbH Immenstadt	monta Klebebandwerk GmbH Immenstadt	Immenstadt im Allgäu
164	Coil coating industries	DE	DE	Coil Coating plant 3 Hydro Aluminium Rolled Products GmbH	Hydro Aluminium Rolled Products GmbH	41515 Grevenbroich
165	Coating of other metal surfaces	BE	BE	ALRO nv	ALRO nv	Dilsen-Stokkem
166	Coating of textiles, foils and paper	BE	BE	Seyntex N.V. - Seyntexlaan 1	Seyntex N.V.	Seyntexlaan 1 - 8700 Tielt
167	Winding wires manufacturing	IT	IT	IRCE SpA, Imola (BO)	IRCE SPA	IMOLA (BO)
168	Flexography and packaging gravure	IT	IT	MASTERPACK SPA	MASTERPACK SPA	VERUNO (NO) PIEMONTE
169	Coating of plastic work pieces	IT	IT	I.P.R.spa	I.P.R.spa	Civitanova Marche
170	Coating of plastic work pieces	IT	IT	Mondial Suole S.p.a.	Mondial Suole S.p.a.	PORTO RECANATI
171	Coating of textiles, foils and paper	IT	IT	Chiorino S.p.A.	Chiorino S.p.A.	Biella Piedmont

Code number	Main sector	Member state	Proposed by:	Installation / Site / Line name	Company name	Town
172	Coil coating industries	BE	BE	ArcelorMittal Liege	ArcelorMittal	Ivoz-Ramet Liege
173	Coil coating industries	ES	ES	ArcelorMittal Lesaka	ArcelorMittal España S.A.	Lesaka
174	Flexography and packaging gravure	DE	DE	Coveris Halle	Coveris Flexibles Deutschland GmbH	Halle in Westfalen
175	Flexography and packaging gravure	DE	DE	Coveris Warburg	Coveris Flexibles Deutschland GmbH	Warburg
176	Coating of other metal surfaces	DE	DE	EOT - Eibach Oberflächentechnik GmbH	Eibach Oberflächentechnik GmbH	Lüdenscheid
177	Coating of furniture and wood materials	DE	DE	Egger Brilon	Egger Holzwerkstoffe Brilon GmbH & Co. KG	Brilon

## 21.2 List of plants participating at the WPC data collection

Abbreviation / Code	Installation/Site name	Company name	MS	Town	Treatment type
<b>SNCF</b>	SNCF E.I.V	SNCF	FR	46130 BIARS sur CERE	Creosote
<b>DE-5</b>	DB Schwellenwerk Schwandorf	DB Netz AG Werk Oberbaustoffe Witten	DE	Schwandorf	Creosote
<b>Track</b>	Track Tec Lipa Sp. z o.o.	Track Tec Lipa Sp. z o.o.	PL	Lipa	Creosote Water-based
<b>C&amp;G</b>	Calders & Grandidge	Calders & Grandidge	UK	Boston	Creosote Water-based
<b>Octo</b>	Octowood	Octowood AB	SE	Kälarne	Creosote Water-based
<b>FBI</b>	FRANCE BOIS IMPREGNES	FRANCE BOIS IMPREGNES	FR	42 210 BOISSET LES MONTROND	Creosote Water-based
<b>DE-9</b>	Imprägnierwerk Wülknitz	Imprägnierwerk Wülknitz GmbH	DE	Wülknitz	Creosote Water-based
<b>DE-8</b>	Zimmer Zäune GmbH	Zimmer Zäune GmbH	DE	Maring-Noviant	Creosote Water-based
<b>Froslev</b>	Frøslev Træ A/S	Frøslev Træ A/S	DK	Frøslev, DK-3360 Padborg	Water-based
<b>Lonza</b>	Arch Timber Protection	Lonza	UK	Wolverhampton	Water-based
<b>Sodra</b>	Sodra Wood Dundee (was Crown Timber)	Sodra Wood Dundee	UK	Dundee	Water-based
<b>WindyM</b>	Windymains Sawmills	Glennon Brothers	UK	Humbie	Water-based
<b>Stella</b>	STELLA S.P.A	STELLA S.P.A. ad Unico Socio	IT	Cuneo (CN)	Water-based
<b>Bitus</b>	Bergs Timber Bitus	Bergs Timber Production AB	SE	Nybro	Water-based
<b>Varberg</b>	Varberg Timber AB	Varberg Timber AB	SE	Varberg	Water-based
<b>Oriel</b>	société forestière ORIEL	ORIEL	FR	88 430 CORCIEUX	Water-based
<b>PivB</b>	PIVETEAU BOIS	PIVETEAU BOIS	FR	85 140 SAINT FLORENCE	Water-based
<b>Paras</b>	Ab Pâras Oy	Ab Pâras Oy	FI	Kruunupy	Water-based
<b>DE-6</b>	Fürstenberg-THP GmbH / Hüfingen	Fürstenberg-THP GmbH	DE	Hüfingen	Water-based
<b>Marga</b>	Margaritelli Ferroviaria SpA /Rodallo	Margaritelli Ferroviaria SpA /Rodallo	IT	Rodallo	Water-based
<b>DE-7</b>	Klenk Holz AG, Werk Baruth	Klenk Holz AG, Werk Baruth	DE	Baruth/Mark	Water-based
<b>ISB</b>	ISB France	Groupe ISB - PBM Import	FR	Site Avenue Louis Martin	Water-based
<b>CO2</b>	Superwood A/S	Superwood A/S	DK	DK-7362 Hampen	CO2

## 21.3 Models for estimating cost benefit

### 21.3.1 EGTEI model and synopsis sheets

*This section will be updated and completed with information from TFTEI work such as the "ERICA VOC" model: " Costs of reduction techniques for large users of solvents [210, TFTEI, 2017] (see also: <http://tftei.citepa.org/en/work-in-progress/costs-of-reduction-techniques-for-large-users-of-solvents>)*  
**WORK IN PROGRESS**

**Description:** EGTEI aims to assess the costs of emission reduction techniques and to provide input data to determine total costs for a given sector of activity, depending on various emission reduction scenarios based on technology dependent penetration rates. The EGTEI approach is to:

- improve the representation of pollution control technology costs for a given sector
- reduce uncertainties by working together with the relevant industry stakeholders
- check traceability of data used
- ensure compatibility with the Regional Air Pollution Information and Simulation (RAINS) model, and facilitate the understanding of aggregated data used in RAINS.

Within EGTEI, an emission reduction cost database has been worked out. In this database, a series of background documents has been developed for about 50 sector activities laid down and condensed in a computer tool named ECODAT. Each sector is represented by one or more reference installations (according to operational size), characterised with sets of different parameters: capacity, annual operating hours, production process, combustion technology used, fuel consumption, production data, flowrates of emissions, plant lifetime, etc. ECODAT has been designed to collect country-specific data.

EGTEI provides default operating costs calculated on the basis of average European parameters, but it gives to national experts the possibility to introduce specific costs for a given country. To ensure transparency, the method used to assess the costs and the various parameters can be found in the background documents.

Sector representation and cost definition have been developed in close co-operation with industry and national experts. In order to facilitate the national experts' work, it has been necessary to find an equilibrium between the most accurate description of a given sector and the need to minimise statistical data to be collected for cost assessment.

**Achieved environmental benefits:** EGTEI data sheets are primarily to assist national experts gather data for VOC emissions for RAINS. However, the synopsis sheets contain helpful information to support the consideration of BAT (see Applicability, below).

**Cross-media effects:** None.

**Operational data:** See individual data sheets for operational data on each industry type.

**Applicability:** EGTEI also provides synopsis sheets. These contain a summary of the industries considered, the reference installations considered, primary (in-process) and secondary (end-of-pipe) abatement measures feasible for each level of reference plant and produce default emission values, abatement efficiencies, investment costs, with variable and fixed operating costs for each combination of options. These are summarised at a European level and may be considered when assessing BAT in the industry.

There are synopsis sheets for all the activities covered by the IED, and therefore this document. The project resources necessarily limited the number and complexity of techniques considered, but the main options have been identified. The sheets only cover the cost-effectiveness of measures to control NMVOC emissions.

The synopsis sheets do not take into account any BAT considerations such as cross-media effects, nor technical or other characteristics of individual installations, such as types of products and their technical limitations.

**Economics:** See individual synopsis sheets.

**Driving force for implementation:** Supplying data for RAINS.

**Example plants:** See synopsis sheets.

**Reference literature:** EGTEI home page: [http://www.citepa.org/forums/egtei/egtei\\_index.htm](http://www.citepa.org/forums/egtei/egtei_index.htm) [81, EGTEI, 2005]

**Table 21.1: Table of EGTEI synopsis sheets relevant to this document**

Revised STS BREF Chapter	Sector/activity	URL to related EGTEI synopsis sheets	IED Annex VII(2) activity code
2	Printing industry		
10	Heatset web offset	<a href="http://www.citepa.org/forums/egtei/34-Synopsis-sheet-heatset-offset-30-09-05.pdf">http://www.citepa.org/forums/egtei/34-Synopsis-sheet-heatset-offset-30-09-05.pdf</a>	1
12	Publication rotogravure	<a href="http://www.citepa.org/forums/egtei/35-Synopsis-sheet-publication-gravure-30-09-05.pdf">http://www.citepa.org/forums/egtei/35-Synopsis-sheet-publication-gravure-30-09-05.pdf</a>	2
11	Flexography and rotogravure, in packaging	<a href="http://www.citepa.org/forums/egtei/36-Synopsis-sheet-packaging-30-09-05.pdf">http://www.citepa.org/forums/egtei/36-Synopsis-sheet-packaging-30-09-05.pdf</a>	3
9	Winding wires	<a href="http://www.citepa.org/forums/egtei/23-Synopsis-sheet-winding-wire-29-09-05.pdf">http://www.citepa.org/forums/egtei/23-Synopsis-sheet-winding-wire-29-09-05.pdf</a>	9
16	Manufacture of abrasives tapes	See: Other coating industries:	8
7	Manufacture of adhesive tape (EGTEI: Adhesive application in industry)	<a href="http://www.citepa.org/forums/egtei/38-Synopsis-sheet-adhesives-30-09-05.pdf">http://www.citepa.org/forums/egtei/38-Synopsis-sheet-adhesives-30-09-05.pdf</a>	16
2	Coating of cars	<a href="http://www.citepa.org/forums/egtei/15-Synopsis-sheet-car-coating-29-09-05.pdf">http://www.citepa.org/forums/egtei/15-Synopsis-sheet-car-coating-29-09-05.pdf</a>	Annex VII(3)
2	Coating of trucks and vans	<a href="http://www.citepa.org/forums/egtei/20-Synopsis-sheet-truck-coating-29-09-05.pdf">http://www.citepa.org/forums/egtei/20-Synopsis-sheet-truck-coating-29-09-05.pdf</a>	Annex VII(3)
2	Coating of truck cabs	<a href="http://www.citepa.org/forums/egtei/21-Synopsis-sheet-truck-cabin-coating-29-09-05.pdf">http://www.citepa.org/forums/egtei/21-Synopsis-sheet-truck-cabin-coating-29-09-05.pdf</a>	Annex VII(3)
2	Coating of buses	<a href="http://www.citepa.org/forums/egtei/22-Synopsis-sheet-bus-coating-29-09-05.pdf">http://www.citepa.org/forums/egtei/22-Synopsis-sheet-bus-coating-29-09-05.pdf</a>	Annex VII(3)
3	Coating of trains	See: Other coating industries	8
3	Coating of ACE (agricultural, construction and similar equipment)	See: Other coating industries	8
4	Coating of ships and yachts	See: Other coating industries	8
5	Coating of aircraft	See: Other coating industries	8



Revised STS BREF Chapter	Sector/activity	URL to related EGTEI synopsis sheets	IED Annex VII(2) activity code
3	Coating of other metal surfaces	See: Other coating industries	8
6	Coil coating	<a href="http://www.citepa.org/forums/egtei/18-Synopsis-sheet-coil-coating-30-09-05.pdf">http://www.citepa.org/forums/egtei/18-Synopsis-sheet-coil-coating-30-09-05.pdf</a>	7
10	Coating and printing of metal packaging	This industry is not covered by a specific EGTEI synopsis sheet. In part (e.g. rigid metal packaging) addressed in the synopsis sheet 'Other coating industries'. Other parts of the industry are related to flexible packing	3 and 8 (in part)
3	Coating of other plastic surfaces	See: Other coating industries	8
14	Coating of wooden surfaces	<a href="http://www.citepa.org/forums/egtei/19-Synopsis-sheet-wood-coating-30-09-05.pdf">http://www.citepa.org/forums/egtei/19-Synopsis-sheet-wood-coating-30-09-05.pdf</a>	10
15	Wood preservation	<a href="http://www.citepa.org/forums/egtei/40-Synopsis-sheet-preservation-wood-30-09-05.pdf">http://www.citepa.org/forums/egtei/40-Synopsis-sheet-preservation-wood-30-09-05.pdf</a>	12
16	Mirrors	See: Other coating industries	8
	Other coating industries:		
16	Abrasives		
3	Trains		
3	ACE (agricultural, construction and similar equipment)	<a href="http://www.citepa.org/forums/egtei/24-26-Synopsis-sheet-general%20industrial-paint-30-09-05.pdf">http://www.citepa.org/forums/egtei/24-26-Synopsis-sheet-general%20industrial-paint-30-09-05.pdf</a>	8
4	Ships and yachts		
5	Aircraft		
3	Other metal surfaces		
10	Metal packaging (in part)		
3	Other plastic surfaces		
16	Mirrors		
17.9	Cleaning techniques (for surface cleaning of products)	<a href="http://www.citepa.org/forums/egtei/27-Synopsis-sheet-surface%20cleaning-30-09-05.pdf">http://www.citepa.org/forums/egtei/27-Synopsis-sheet-surface%20cleaning-30-09-05.pdf</a>	4 & 5

### 21.3.2 Regional environmental costing model (MKM, MilieuKostenModel)

**Description:** In Flanders, Belgium, an environmental costing model (MilieuKostenModel or MKM) has been developed in parallel with the EGTEI work. With this tool, it is possible to obtain an overview of potential abatement measures, their costs and emission reduction potential, and to find cost efficient or least cost solutions.

The interactions and trade-offs for complex situations are taken into account in the MKM by means of mixed integer programming. The model can be used to optimise (e.g. the least cost solution to reduce emissions, or the marginal cost curve for a particular pollutant) and to simulate (e.g. the impact of more stringent environmental objectives on the least cost solution, or what is the impact of the reduction of polluting activities) for one or multiple pollutants at the same time.

A background report describes the definitions used such as environmental costs and cost efficiency, and the methodology to analyse the cost efficiency of abatement measures.

MKM was devised to determine the costs of environmental policy and to contribute to a more efficient environmental policy by indicating how environmental targets can be realised in a cost effective way. The brief was to:

- develop a coherent database with environmental measures, their reduction potential and costs
- develop a tool to allocate emission reduction efforts between different target groups in a cost effective way
- develop a tool to take into account multiple pollutant effects
- develop a tool to analyse the cost effectiveness of policy instruments
- develop an instrument that can be linked to other models such as ecological models, economic models, (e.g. RAINS).

Depending on the data available, emission sources are identified on an aggregated level (e.g. sector or industry level) or individual source level (e.g. individual companies). The format of the database makes it possible to describe emission sources as individual installations or as so-called 'reference installations'. A 'reference installation' is a representative category of installations for which the same emission abatement measures are available and for which a particular abatement measure has similar abatement results and costs. For each pollutant, emissions are linked to an activity that is the source of the pollution, e.g. amount of solvent consumed. Consequently, the MKM can be used to predict emissions based on the evolution of the activities or emission factor. Also, it is possible to compare data with the input of other models, e.g. RAINS, and link the MKM with, e.g. input-output tables or general equilibrium models.

In addition to emission data, energy consumption, operational hours, capacity, etc. can be entered in the database for each (reference) installation.

For each abatement measure, the following information can be entered in the database: investment costs, operational costs, lifetime, capacity, reduction efficiency.

**Achieved environmental benefits:** No data submitted.

**Cross-media effects:** No data submitted.

**Operational data:** No data submitted.

**Applicability:** The development of the model is focused on one criterion: cost effectiveness. Nevertheless, other criteria can play a significant role in determining the environmental policy such as environmental effectiveness and feasibility. It is important to mention that the environmental costing model (MKM) is not a tool to carry out an investment analysis for a specific company. The model is a tool to support the Flemish Government in estimating the costs of the environmental policy for different target groups. Such information can be used, for example, to allocate emission reduction efforts between target groups.

Measures discussed in this document that were analysed with this model are, e.g. for the coating sector:

- painting techniques, i.e. conventional (see ~~Section~~), high solids (see Section 17.7.2.1), water-based (see Section 17.7.2.2), powder coating (see Section 17.7.2.4) and UV-cured paint (see Section 17.7.2.4)
- waste gas treatment techniques, i.e. adsorption to activated carbon (see Section 17.10.6.3), thermal oxidation (see Section 17.10.5.2) and biological treatment (biofilters) (see Section 17.11.7).

More measures are described in this document to reduce VOC emissions, but not all can be analysed with this model.

The following industries can be consulted in the database of the MKM: coating, printing, degreasing, adhesives and automobiles. As an example of the output of the tool, the results for the coating sectors are shown in Table 21.2 and Table 21.3

\*Note: these data are supplied from the MKM and the footnotes should be referred to.

**Economics:** No data submitted.

**Driving force for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:**

The MKM page: <http://www.emis.vito.be/index.cfm?PageID=371&T=0&S=0>

The background report: (Meynaerts E., Ochelen S., Vercaemst P., Milieukostenmodel voor Vlaanderen – Achtergronddocument, 2003).

[48, VITO, 2005] [78, TWG, 2005]

**Table 21.2: Average costs and VOC reduction potential of all the measures analysed by the model**

Technique	Operational cost of paint in EUR per kg	Energy cost in EUR per hour	Residues in EUR/kg	VOC content of paint (presumed to be wt-%)	
Conventional	3.11	6.7	0.3		
High solids	3.5	6.4	0.3	<30 %	
Water-based	8.43	7.21	0.2	7.50 %	
Powder coating	15.39***	2.9	0	0 %	
UV paint	3.78***	3.76	0	3.50 %	
	Investment cost in thousand EUR per 1000 m <sup>3</sup> /h	Activated carbon in EUR per kg	Operational cost	VOC reduction (%)	VOC emission concentration
Activated carbon*	5 – 10	1.2	EUR 0.5 – 2.30 per m <sup>3</sup> /h with initial VOC conc. of 1 – 10 g/m <sup>3</sup>	85 %	5 – 100 mg TOC/m <sup>3</sup>
Thermal oxidation**	5 – 40		EUR 0.45 – 4.50 per 1000m <sup>3</sup> /h (extra energy)	95 – 99 %	<20 – 50 mg TOC/m <sup>3</sup>
*Reduction option when VOC emissions are between 8 to 20 tonnes a year, 85 % reduction **Reduction option when VOC emissions are >20 tonnes a year, 95 % reduction ***Sections 17.7.2.4 and 17.7.2.8 give costs of EUR 30.01 – 5.38/kg for both radiation cured and powder coating paints Source: [48, VITO, 2005]					

Table 21.3: Possible cost-effective measures for the reduction of VOC emissions per industry

Industry	Number of employees	Possible in-process measures <sup>1</sup>			Possible end-of-pipe measures	
Metal surfaces	1 - 19	60 % high solid	40 % water-based	50 % powder		
	20 - 199	80 % high solid	40 % water-based	50 % powder		
		100 % high solid		60 % powder		Incinerator
						Incinerator*
	200 - 499	80 % high solid		50 % powder		
					Activated carbon*	Incinerator
						Incinerator*
	500 - 999	80 % high solid		50 % powder	Activated carbon*	
		80 % high solid				Incinerator
	1000 - 1000+	80 % high solid				
	100 % high solid	Water-based				
Metal packaging – barrels	20 - 99					Incinerator*
	100 - 199					Incinerator*
	500 - 999	Optimise cleaning agents				
Furniture	10 - 499			80 % powder (for those who still use wet coatings)		
	5 - 199		60 % water-based	40 % powder	Activated carbon*	
Ships	10 - 499	60 % high solid				
Trains	10 - 1000+	70 % high solid		30 % powder	Activated carbon*	Incinerator*
Others	1 - 49	60 % high solid		30 % powder		
	50 - 99		30 % water-based	30 % powder		
	100 - 199	60 % high solid		30 % powder		
	200 - 499	No additional measures				
	500 - 999				Activated carbon	

Industry		Number of employees	Possible in-process measures			Possible end-of pipe measures	
WOOD	Furniture	1 - 9	30 % high solid	30 % water-based			
		10 - 19	30 % high solid	30 % water-based			
		20 - 49	30 % high solid	30 % water-based	UV paint	Activated carbon*	<i>Biofilter*</i>
				water-based	UV paint		
		50 - 99	30 % high solid	30 % water-based	10 % UV	Activated carbon*	<i>Biofilter*</i>
		100 - 199	30 % high solid	30 % water-based	10 % UV		
		200 - 499	30 % high solid	30 % water-based	10 % UV	Activated carbon*	Incinerator*
	Cabinet work	1 - 499	30 % high solid	40 % water-based	10 % UV		Incinerator
	Others	5 - 199	30 % high solid	40 % water-based	10 % UV		
PLASTICS	Plastic	1 - 4	50 % high solids	<i>30 % water-based</i>			Incinerator*
		5 - 9	50 % high solids				Incinerator*
		10 - 19	50 % high solids				Incinerator*
		50 - 99	50 % high solids	<i>40 % water-based</i>			
		100 - 199		<i>50 % water-based</i>			
		200 - 499	50 % high solids	<i>40 % water-based</i>			Incinerator*
		500 - 999	50 % high solids		UV paint		Incinerator
		<p>1 The percentages of the possible measures relate to maximum technical uptake, they are not based on cost benefit</p> <p>*Not enough data were collected on the survey to draw a conclusion. In these cases, a general rule was used: incinerators are technically applicable when VOC emissions are &gt;20 t/yr and adsorption to activated carbon and biofilters are technically applicable when VOC emissions range from 8 - 20 t/yr. However, Section 17.10 of this document shows choice is related to air volume and concentration, not total consumption</p> <p>Measures in italics were rejected and were not taken up into the model as they have higher costs and lower efficiencies compared to other measures.</p> <p>Source: [48, VITO, 2005]</p>					

## Calculation of VOC emissions and the units used

*Proposed for deletion as information is included in sector-specific chapters*

[130, ADEME, 2006] [60, COM, 1996, 73, COM, 1999] [97, TWG, 2006]

All activities within the scope of this document are regulated by the SED (Council Directive 1999/13/EC of 11 March 1999) and IPPC applies to the larger installations within SED control. The Preface to this document describes the interface between the two directives. In the interests of better regulation and simplification, this document (the STS BREF) uses the determination of VOC emissions and the values used to express them as described in the SED. This is particularly important for the expression of emission values related to BAT. This implies that installations are able to use the SED reduction scheme where the SED gives no total emission limit values for that industry.

There are various industry exceptions to using the SED values, which are explained in the various sections, such as:

- heatset offset printing, where the emission values related to BAT are expressed as wt % of the ink consumption. This allows the effect of the BAT to be measured, whereas the % solvent input (which the SED uses) does not
- the coating of trains and manufacturing of mirrors, where the information provided and from which BAT were derived, were based on gm VOC/m<sup>2</sup> painted
- coil coating and metal packaging, where m<sup>2</sup> were identified as appropriate production throughout measures
- wood preservation, where the information provided and from which BAT were derived were based on percentage reduction in VOC emission based on solvent input.

### 21.3.3 Compliance with the Industrial Emissions Directive

*This section will be updated and completed at a later stage*  
**WORK IN PROGRESS**

The IED regulates the emissions of volatile organic compounds (VOC) due to use of organic solvents in different types of activities and installations.

According to Article 32 of the IED Directive, two different options are offered to demonstrate compliance with the legal requirements:

*'All installations shall comply with:*

*(a) either the emission limit values in waste gases and the fugitive emission values, or the total emission limit values, and other requirements laid down in Annex IIA;*

*or*

*(b) the requirements of the reduction scheme specified in Annex VII(5).'*

For either option, there are specific exceptions where the operator must demonstrate that BAT is being used.

#### 21.3.3.1 Emission limit values (ELVs) and fugitive emissions (IED Annex VII)

Each type of industry must comply with the values given in the tables in Annex IIA. The ELVs are expressed in mg C/m<sup>3</sup> at standard conditions, and fugitive emissions as percentage of the

solvent input. Total emission values (where given) are expressed as industry-specific terms, such as g VOC/kg of product (for winding wires), g VOC/m<sup>2</sup> e-coat surface area for vehicles, etc.

### 21.3.3.2 Emission reduction scheme (IED Annex VII)

Annex VII of the IED states:

#### ***‘Principles***

*The purpose of the reduction scheme is to allow the operator the possibility to achieve by other means emissions reductions equivalent to those achieved if the emission limit values were applied. To that end an operator may use any reduction scheme, specially designed for his installation, provided that in the end an equivalent emission reduction is achieved...’*

The implementation and validation of an emission reduction scheme therefore ensures that the yearly VOC emission flux will not be higher than the flux achieved by meeting the emission limit values for all waste gases and fugitive emissions. The interest of an emission reduction scheme for operators is to be able to think of their processes as a whole and to have flexibility about their choices for emission reduction. Additional efforts and investments will be made where they are technically and economically most effective. This is consistent with the IPPC Directive, Article 9(4):

*‘... the emission limit values and the equivalent technical parameters and technical requirements referred to in paragraph 3 (permit conditions) shall be based on BAT, without prescribing the use of any technique or specific technology, but take into account the technical characteristics of the installation, its geographical location and the local environmental conditions...’*

Annex VII to the IED describes a reduction scheme where a constant solid content of product can be assumed for coatings, varnishes, adhesives or inks.

A target emission is calculated on based on the annual solids and the fugitive emissions given in Annex IIA. They are expressed as a percentage of the unabated emissions. In the IED, this unabated emission is called the ‘reference emission’. Where no substitution has taken place, the unabated emissions are equal to the solvent input. Where some substitution or other emission controls on fugitive sources have been applied, the unabated emissions need to be estimated. The method in Annex VII to the IED can generally be used for this purpose. The annual reference emission is calculated as follows (quoted exactly from the IED):

- a) The total mass of solids in the quantity of coating and/or ink, paint or adhesive consumed in a year is determined. Solids are all materials in coating, inks, paints or adhesives that become solid once the water or the volatile organic compounds are evaporated.*
- b) The annual reference emissions are calculated by multiplying the mass determined in (a) by the appropriate factor listed in Table 21.4.*

**Table 21.4: Factors in IED for determining annual reference emission values**

<b>Activity</b>	<b>Multiplication factor</b>
<i>Rotogravure printing; flexography printing; laminating as part of a printing activity; painting as part of a printing activity; wood coating; coating of textiles, fabric film or paper; adhesive coating</i>	4
<i>Coil coating, vehicle refinishing</i>	3
<i>Food contact coating, aerospace coatings</i>	2.33
<i>Other coatings and rotary screen printing</i>	1.5

The target emission can be expressed as wt-% (i.e. % VOC of the solids, more usually as kg VOCs/kg solids, as defined in the IED). As the IED allows any equivalent reduction scheme to be used, provided it satisfies the principles outlined in Annex VII(5), VOC target emissions may then be expressed as VOC t/yr (for a specific installation of known throughput), kg VOC/m<sup>2</sup> coated, kg VOC/production item produced.

For example, regarding the flexo and packaging gravure printing process, the calculation is as follows:

The average solvent content of press ready inks, paints and adhesives in flexo and packaging gravure is approximately 80 %. The solid matter in these products accounts for 20 % of the total weight, and thus ¼ of the solvent weight. The unabated emissions ('reference emission') can be estimated by multiplying the weight of all the solids, of both solvent-based and water-based products, by four.

### 21.3.4 Precision

*This section will be updated and completed at a later stage – to be merged under the general considerations for the Solvent Mass Balance*  
**WORK IN PROGRESS**

The Solvent Emissions Directive describes a method, simple at first sight, by which fugitive emissions can be determined in plants where captured solvent vapours are incinerated. The principle of this method is that the amount of solvent sent to the incinerator is subtracted from the total solvent input. The difference between the two quantities must have disappeared; most of it as fugitive emissions.

In practice, this method can suffer from a lack in accuracy. For example, when the method given in the Directive is used, fugitive emissions that are, in reality, amounting to approximately 15 % of the input, can easily be quantified as anything from 0 to over 40 %.

If the difference is calculated between two almost equal numbers such as 'input' and 'captured emissions', then the outcome, which should represent the fugitive emissions, is a relatively small number. The inaccuracy in the resulting small number, however, is equal to the sum of the inaccuracies in the two original, large numbers. Thus, all the inaccuracies in the two original numbers are included in the fugitive emissions.

The main problem lies in the difficulty of quantifying captured emissions. This requires multiplication of the airflow, solvent concentration and time. The airflow and concentration vary over time, and neither can be measured accurately. The error in the result is greater than 20 %.

Options to address the inaccuracies are to determine the fugitive emissions directly (see Annex 21.4) or to derive the unabated emissions from the actual solvent input (see Annex 21.5).

The following example shows how a typical range in concentration and flow can show a 4-fold range in amount of VOC emitted.

Where O1 is the emission in waste gases.

$$O1 = \frac{(\text{concentration } c \text{ in mg C/Nm}^3) \times (\text{volume } v \text{ m}^3/\text{h}) \times (\text{operating hours in time period})}{\text{time period}}$$

For a theoretical installation operating 5760 hours per year (24 hour a day, 5 days a week, 48 weeks a year), with waste gas flows  $v = 100000 \text{ m}^3/\text{h}$  and the periodic monitoring giving values varying between 5 and 20 mg C/Nm<sup>3</sup>. The annual emission calculated for each end of the range:



where  $c = 5 \text{ mg C/Nm}^3$ ,  $O1 = 2880 \text{ kg}$  (2.88 tonnes)

where  $c = 20 \text{ mg C/Nm}^3$ ,  $O1 = 11500 \text{ kg}$  (11.5 tonnes).

Depending on the type of activity and the installation, the variation between the lowest determinand and the highest may be considerable (see the Monitoring REF).

### 21.3.5 Application efficiency of the coating

Calculating VOC emissions according to the reduction scheme described in the IED, Annex VII(5) does not take into account an improvement in the application efficiency, because the calculation is based on the ratio of VOC to solids: if the quantity of solids is decreased, the ratio kg VOC/kg solids remains the same. This should be considered when setting emission targets and ELVs. Options are to set a total emission per year or per production unit.

For example, in an installation with a paint consumption of 2000 tonnes per year, the corresponding solvent consumption is 1500 tonnes (75% solvent consumption: i.e. a ratio of 3 kg of VOC/kg of solids). The spray guns have an application efficiency of 20%. According to the IED:

the reference emission target emission =  $500 \text{ tonnes} \times 4 = 2000$ .

the target emissions =  $0.25 \times \text{reference emissions} = 0.25 \times 2000 = 500 \text{ tonnes of VOC}$ .

Reductions in emissions can be achieved by one or more of the following:

- installing an end-of pipe technique to reduce VOC emissions to 375 tonnes (where the ratio remains 3 kg of VOC/kg of solids)
- by using water-based (WB) paints (for example, the use of 2000 tonnes of WB paints with a solvent consumption of 18.75% gives VOC emissions of 375 tonnes: the ratio is 0.75 kg of VOC/kg of dry matter)
- by applying solvent-based paints (with a ratio of 3 kg of VOC/kg of dry matter) with a much higher efficiency: applying the same solvent-based paints with an application efficiency of 80% leads to a paint consumption of 500 tonnes (instead of 2000 tonnes) and thus VOC emissions of 375 tonnes.

## 21.4 Measuring fugitive emissions – direct method

*This section will be updated and completed at a later stage – to be merged under the general considerations for the Solvent Mass Balance*  
**WORK IN PROGRESS**

[16, Aminal, et al., 2002] [38, TWG, 2004] [97, TWG, 2006]

### Step 1: Identify all sources of fugitive emissions within the plant

All solvent vapours that are not routed to the incinerator escape to the air and contribute to the fugitive emissions. Most industries considered in this document have many sources of fugitive emissions. The following is a case study in some ten flexible packaging plants in Flanders, Belgium, and the Netherlands. However, the principles described in the following steps are readily transferable to other industries. Most plants will have a number of sources and most of these will only result in small or extremely small emissions. In most cases, there are just one to three sources in a plant which make a substantial contribution to the fugitive emissions. More than one emission factor may need to be determined for a source, to improve the accuracy or for convenience.

A flexible packaging plant has many sources of fugitive emissions. The sources identified so far are listed below, although most plants will only have a few of these. In some cases, there may be more sources, or another classification may be more convenient.

Sources of fugitive emissions for flexible packaging are:

- press room ventilation during printing
- dryer ventilation during make ready
- dryer ventilation while waiting
- local exhaust between press units
- cleaning department
- ink mixing department
- solvent content of water-based inks, paints and adhesives
- solvents used on production machines not connected to the incinerator
- residual solvent in products
- solvent discharged to water
- solvent emissions from waste water treatment plants
- vapour losses from tanks, etc.

Double counting should be avoided. For example, if the ink is mixed next to the press then the evaporated solvent will be removed by the local exhaust between press units and the room ventilation and does not need to be quantified separately.

### Step 2: Study the ventilation system and ensure that it works as expected

In production areas in particular, the design of the ventilation system determines which fugitive emission sources are present, and how the emitted quantities must be estimated or measured. The ventilation systems do not normally work as assumed in the plant. Either the system was built in a different way than remembered or recorded, and/or the system control settings were completely changed during the course of time. A ventilation system that actually operates as expected is very rare.

Some examples that were actually encountered in practice are:

- the actual duct system was different from the drawing. Fans and ducts had been installed or removed, and the modifications had not been documented accurately

- automatic positive and negative pressure controls did not operate as designed. Printing plants which expected to be working above atmospheric pressure were actually working at subatmospheric pressure, and the other way round
- some components of the ventilation system showed to have more functions than expected. A fan for aqueous paints on one of the printing units was also found to be connected to the local exhaust between the press units
- significant airflows were shown to exist between different parts of the building.

As long as the operation of the ventilation system is not perfectly in order, there is no point in measuring or estimating fugitive emissions that are affected by it. If the settings of the ventilation system need to be adjusted later, the estimation and measurements will be of no use. Hence, the first action should be to assure complete understanding of the ventilation system in the production areas. The ducting and fans need to be compared with the drawings. The maintenance status should be checked. Poor maintenance and cleaning can reduce the airflow by as much as 50 %. It is good practice to correct any substandard maintenance before carrying out any measurements.

When comparing the design with the current system, questions must be asked such as the following:

- have filters and drive belts been replaced according to suppliers maintenance schedules?
- are the fan blades and heat exchangers clean?
- where are the exhausts?
- where are the inlets for fresh air?
- which exhausts are connected to the same duct?
- which fan serves what part of the system?
- when are dampers and valves automatically opened or closed?
- what automatic controls are incorporated?
- what measurements are provided for them?
- what are the theoretical flowrates of the fans?
- how are the control systems supposed to operate?
- what is the difference between summer and winter control modes?

In most cases, there is a clear difference between theory and practice. It has then to be decided what is actually required and the ventilation settings need to be adjusted accordingly. It then has to be verified if the ventilation system actually produces the required results in the different stages of the production process (e.g. make ready, printing, cleaning, etc.). In practice, this may be relatively easy to do. For example, the direction of the airflow through doors, windows and other openings can be easily established using a thin, narrow strip of plastic film. Fugitive emissions can only be determined once the ventilation system is adjusted as required by plant management. Obviously, management will also need to ensure the improved regime is maintained.

### **Step 3: Make a substantiated estimate for each source, in the form of an emission factor multiplied by a production parameter**

The emissions of every source with emissions that are not negligible have to be estimated. In this step, the order of magnitude needs to be established. Later it will be decided if the emissions are high enough to warrant additional measurements. Obviously, the estimates should have a secure basis, but at this stage the number of measurements should be minimised. The aim is to only use data already available within the plant, and data which are easily measured. Below are some examples of useful information that is already available in the plant, or which can easily be measured:

- fan capacities, as specified by their manufacturer
- information about occupational exposure to solvents
- measurements of residual solvent in products, carried out for customers
- quantity of bulk solvents, inks, paints and adhesives received
- simple experiments in the ink mixing department
- simple solvent balances for the cleaning department, etc.
- concentration measurements with a PID at local exhausts
- verification of the direction of the pressroom ventilation flow.

The example in Table 21.5 relates to a plant with an annual input of 1000 tonnes of solvent. The example clearly shows how only two out of the eleven sources account for over 70 % of the fugitive emissions.

**Table 21.5: Emissions related to sources from a plant processing 1000 tonnes of solvents**

Source	Emissions in kg	% of input	% of fugitive
Pressroom ventilation during printing	9000	0.90	8.0
Dryer ventilation during make ready	5400	0.54	4.8
Dryer ventilation while waiting	22500	2.25	20.0
Local exhaust between press units	56550	5.66	50.3
Cleaning department	8750	0.88	7.8
Ink mixing department	7500	0.75	6.7
Solvent content of water-based inks, etc.	2500	0.25	2.2
Residual solvent in products	200	0.02	0.2
Solvents discharged in water	-	-	-
Solvent emissions from waste water treatment plant	-	-	-
Vapour losses from tanks, etc.	67	0.01	0.1
<b>Total</b>	<b>112467</b>	<b>11.26</b>	<b>100.1</b>

At this stage, another option would be to reduce the emissions from the major sources or to eliminate them completely before doing any additional measurements. For example, if sufficient incinerator capacity were available, the local exhaust between press units or the exhaust of the cleaning department could be connected to the incinerator. This would eliminate these sources of fugitive emissions completely.

#### **Step 4: Determine which of the sources need more accuracy**

The estimates made in Step 3 are not particularly accurate. However, they clearly indicate that the magnitude of the fugitive emissions varies greatly between sources. Vapour losses from tanks are very small, while the local exhaust between the press units is particularly important.

Now the accuracy of the calculated total fugitive emission needs to be determined. The emission parameters which need more accuracy, must be selected. This is done by a worst case approach: the maximum possible error for each source is estimated, and the resulting maximum potential fugitive emissions from the source in question are calculated. The total of all these maximum potential emissions is the 'worst case'.

Most emission estimates made in Step 3 were calculated by multiplying two or more fairly inaccurate figures. For example, a theoretical airflow may have been multiplied by an indicative concentration measurement and an estimated number of running hours. In such a case, the inaccuracy in each of the parameters needs to be estimated separately and this information is used to calculate the potential maximum emissions from each source, as if the largest possible potential error did indeed occur. The result is the maximum emissions possible from the source in question.

The maximum emissions possible from all the different sources are then added up to calculate the maximum overall fugitive emissions; as if the initial emission estimates for each and every source had been too low. This is a very conservative approach. It is equally likely that the emission estimates were not too low, but too high. In that case, the actual fugitive emissions would be lower than the estimates. In reality, errors to both sides will be made and the actual emissions will be closer to the initial estimate than would be assumed on the basis of the calculation of the potential maximum emissions.

The example in Table 21.6 shows the estimation of the maximum error for each source. Note, however, that a large part of the inaccuracy is due to the limited amount of information about ventilation flows and solvent concentrations.

**Table 21.6: Example of a possible outcome of the calculation of inaccuracies**

Source	Fugitive emissions as % of input	Max. error factor	Max. % of input
Pressroom ventilation during printing	0.90	2.25	2.03
Dryer ventilation during make ready	0.54	1.50	0.81
Dryer ventilation while waiting	2.25	2.00	4.50
Local exhaust between press units	5.66	2.25	12.72
Cleaning department	0.88	2.00	1.75
Ink mixing department	0.75	1.50	1.13
Solvent content of water-based inks, etc.	0.25	1.25	0.31
Residual solvent in products	0.02	1.25	0.03
Vapour losses from tanks, etc.	0.01	1.00	0.01
<b>Total</b>	<b>11.26</b>		<b>23.29</b>

The worst case figures obtained in this way can still easily amount to double the original estimate. Some sources will be so small that they would not affect the outcome, irrespective of how precisely they are measured. In this example these are:

- solvent content of water-based inks, paints and adhesives
- residual solvent in products
- vapour losses from tanks.

There is no point in investigating these sources in any greater detail. Two of the sources on the list are clearly much more important than the others:

- local exhaust between press units
- dryer ventilation while waiting.

These sources require further investigation, but together they account for over 70 % of the fugitive emissions.

Note: this is only an example! In practice, different sources may be the ones with high or low emissions.

#### **Step 5: Improve the inaccurate estimates for large sources**

The scope, depth and detail of the further investigations will depend on the objectives. In most cases, the inaccuracy of only two or three sources will have to be reduced to obtain a significant improvement of the outcome in the worst case approach.

The further investigation needs to be tailored to the specifics of the converting plant. As stated earlier: further investigation is only necessary for sources of fugitive emissions that are both relatively large and uncertain.

This step (Step 5) describes how the inaccuracy of most of the initial estimates can be reduced. In cases where airflow and solvent concentration are being multiplied, an obvious option for improvement of the estimates is to actually measure the concentration. This can be done rather easily by using passive samplers. Where the solvent losses from a source can be determined with scales, the number of weighings could be increased to improve accuracy. As an example, results of the improvement of the accuracy are given in Table 21.7

**Table 21.7: An example showing results of the improvement of accuracy**

Source	Emissions in kg	% of input	% of fugitive emissions
Pressroom ventilation during printing (positive pressure)	9000	0.90	8.0
Cleaning department	8750	0.88	7.8
Ink mixing department	7500	0.75	6.7
Solvent content of water-based inks, etc.	2500	0.25	2.2
Residual solvent in products	200	0.02	0.2
Solvents discharged in water	-	-	-
Solvent emissions from waste water treatment plant	-	-	-
Vapour losses from tanks, etc.	67	0.01	0.1
<b>Subtotal not investigated further</b>	<b>28017</b>	<b>2.81</b>	<b>21.1</b>
Dryer ventilation during make ready	8000	0.80	6.0
Dryer ventilation while waiting	24750	2.48	18.6
Local exhaust between press units	72200	7.22	54.3
<b>Subtotal of sources investigated in detail</b>	<b>104950</b>	<b>10.50</b>	<b>78.9</b>
<b>Total fugitive emissions</b>	<b>132967</b>	<b>13.31</b>	<b>100</b>
<b>Previous result (before additional investigation)</b>	<b>112467</b>	<b>11.25</b>	

\*Note: Subtotal not investigated further as a percentage of fugitive emissions should be 25 %

In this example, the additional investigation has greatly increased the accuracy of three of the eleven sources. The worst case now only differs a few per cent from the actual estimate. As an example, the results of the new estimates of the accuracy are given below.

Example: Increased accuracy as shown in Table 21.8 below.

**Table 21.8: An example showing results of the increased accuracy**

Source and notes	Estimated % of input	Factor max. residual error	Max. % of input improved estimate
Dryer ventilation during make ready	0.80	1.20	0.96
Dryer ventilation while waiting	2.48	1.20	2.97
Local exhaust between press units	7.22	1.20	8.66
Other sources (unchanged)	2.80		5.24
<b>Total</b>	<b>13.30</b>		<b>17.83</b>
<b>Previous result</b>	<b>11.25</b>		<b>23.28</b>

Please note that here only the potential errors that result in increased emissions are being calculated. Errors resulting in reduced emissions are, however, equally likely.

If the fugitive emissions have to be determined more accurately still, other emission sources can be considered for further investigation. In this example, the cleaning department and pressroom ventilation are likely candidates. One-third of the remaining difference between the actual estimation and the worst case (4.5 %) in this example is associated with the cleaning department, and one-fifth with the room ventilation.

**Step 6: Establish a record keeping system from which the annual production parameters can be easily derived**

Simplicity starts by choosing the right parameters. Where possible, they should be based on information that is already being collected. However, it should be determined if the figures obtained from other records do in reality accurately reflect the parameter which the emission factor refers to, and caution is needed. Examples of potential discrepancies between the existing records and the required parameters:

- waiting hours and other stops as recorded in the production department may occur both during make ready or during printing. For the calculation of fugitive emissions, however, only the periods in which the printing units contain ink, but are not actually producing, matter
- production hours (as needed to calculate the emissions from the exhausts between the press units) may not, according to production records, include waiting hours and other stops during printing. However, for the calculations, the full period during which the unit contains ink needs to be established
- if some of the ink is not mixed in the ink mixing department but at the press, the resulting solvent losses will go to the press room ventilation and local exhausts. This may lead to double-counting.

**Step 7: Calculate the annual emissions from each source by multiplying the production parameters and related emission factors**

This step does not need further explanation.

**Step 8: Include the results in the annual solvent management plan and compare the fugitive emissions with the limit value**

This step does not need further explanation.

**Step 9: Determine new emission factors if there is a significant change in the range of equipment, operations or ventilation**

New emission factors must be determined if there are significant changes in the plant. A significant change may be a change in the ventilation system of the production areas, purchase of new machines, sale of old machines, a substantial change in the product range, or changes in the operating methods.

Determining the emission factors is not, in practice, a one-off activity. Once the plant becomes accustomed to dealing with fugitive emissions, the awareness of these emissions will also increase. This in turn will lead to improvements in the records, a repeat and recheck of measurements, and a wish to improve the accuracy of less important emission factors. Furthermore, options will be identified to reduce fugitive emissions. This will also lead to new emission factors.

### 21.4.1 Application to the printing sector

**Description:** This method was tested in two Flemish flexible packaging plants, a very large packaging gravure plant and a medium sized flexographic plant. It is based upon direct measurements of the fugitive emissions. The capture efficiency is the percentage of the evaporated solvents that are exhausted with the waste gases. The remainder escapes as fugitive emissions.

#### **Introduction and terminology of the alternative (direct) method**

Sources of fugitive emissions: Fugitive emissions in a printing plant have many different causes. They arise during printing, cleaning, mixing of inks, transferring of solvents, etc. Each of these activities is a 'source' of fugitive emissions. It is possible to allocate the fugitive emissions in a plant to some 10 or 20 different 'sources'.

Emission factor: The more frequently an activity is undertaken, or the longer it takes, the greater the fugitive emissions will be. Mixing 20 drums of ink will produce twice as many fugitive emissions as mixing 10 drums. Printing for four hours results in greater fugitive emissions than printing for two hours.

An emission factor can be determined for each source. This factor indicates the quantity of fugitive emissions for each time or every hour that the activity is carried out.

Emission factors need to be determined only once. They are specific to a machine and a working method. If neither machine nor working method changes, the emission factor also remains unchanged.

Production parameter: In order to calculate the emission, the emission factor needs to be multiplied with a production parameter. This production parameter is a measure of the activity of the source of fugitive emissions in question. The larger the production parameter, the bigger the fugitive emissions.

Examples: For cleaning operations, the number of times the cleaning unit is used could be employed as the parameter, and for mixing ink the volume of ink that was mixed.

Effective records need to be kept to produce the production parameters.

In short, the method amounts to the following:

- estimate or measure the relevant emission factors and set up a record-keeping system for the annual production parameters. This has to be done only once
- calculations on fugitive emissions have to be carried out each year. This is done by multiplying the production parameters for the year in question by the emission factors.

Obviously, the most difficult step is to determine the emission factors. This is done in two or more stages. The first step is to make a well substantiated estimate. This is done for all the different sources of fugitive emissions. No further action is required for the large number of sources that show very low emissions. The second step is only carried out for a small number of larger sources, where more accurate measurements are taken.

#### **Accuracy**

The production parameters can be determined accurately. Preferably, these parameters are figures that are already part of the production records, or that have to be collected anyway for other parts of the solvent management plan.



Examples of such parameters are the number of operating hours of production equipment, the number of orders processed on each machine, the volume of ink purchased, and the number of tonnes of ink mixed. The parameters are always measures of the activity: the higher the parameter, the higher the associated fugitive emissions must be.

The emission factors are a measure of the emissions per unit of activity. For example, the loss of solvent per kilo of mixed ink, or the loss of solvent through the local exhaust between the press units per operating hour.

The accuracy level of the emission factors is variable. The more extensive the measurements and the investigation are, the more accurate the factors will be. The different sources of fugitive emissions do not all need the same level of accuracy.

Accuracy can also be increased by using more than one emission factor for an activity. Instead of using one emission factor for all ink mixing operations, one could distinguish between mixing large and small batches of ink, mixing on hot or cold days, and mixing by hand or by machine. In other words, either one or five different factors could be determined. In the latter case the accuracy will be greater.

To determine more than one emission factor per activity or increasing their accuracy will however, also increase the amount of work. It is not productive to spend a lot of time on a minor source which hardly contributes to fugitive emissions. It is, therefore, advisable to start by estimating the order of magnitude of the emissions from each source, and then afterwards determine which of the sources need the most accurate emission factors.

The required accuracy for a source depends on two different issues:

1. the magnitude of the overall fugitive emissions: if the overall fugitive emissions are considerably below the limit value then the potential error is allowed be relatively large.

Example: At a limit value of 20 % (for the IED), an actual emission of between '5 and 10 %' would be acceptable, but an actual emission of between '15 and 30 %' would not be. In the latter case the accuracy needs to be increased.

1. contribution of the source to the overall emissions: if the accuracy of the overall figure has to be improved then one should focus on the sources which are both relatively large and have a low accuracy.

Example: Given a limit value of 20 % and actual emissions of 15 to 30 %, with a contribution from the ink mixing department of 1 to 2 % and a contribution of the local exhaust between press units of 10 to 20 %, it would obviously be beneficial to improve the accuracy of the second source.

**Achieved environmental benefits:** The accuracy in monitoring fugitive emissions is considerably improved. The insight gained on the origin and cause of the fugitive emissions, contributes to the reduction of these emissions.

**Cross-media effects:** No data submitted.

**Operational data:** The method has been tested in flexible packaging printing plants.

**Applicability:** Flexible packaging plants applying a destructive abatement technique.

**Economics:** No data submitted.

**Driving force for implementation:** No data submitted.

**Example plants:** No data submitted.

**Reference literature:** [38, TWG, 2004]

WORKING DRAFT IN PROGRESS

## 21.5 The common cases for mass balances

This section will be updated and completed with information from various sources e.g. [190, ESVOC, 2017] [198, DE, 2017] [204, UNECE, 2016] [205, BE, 2005] [209, ACEA, 2017]

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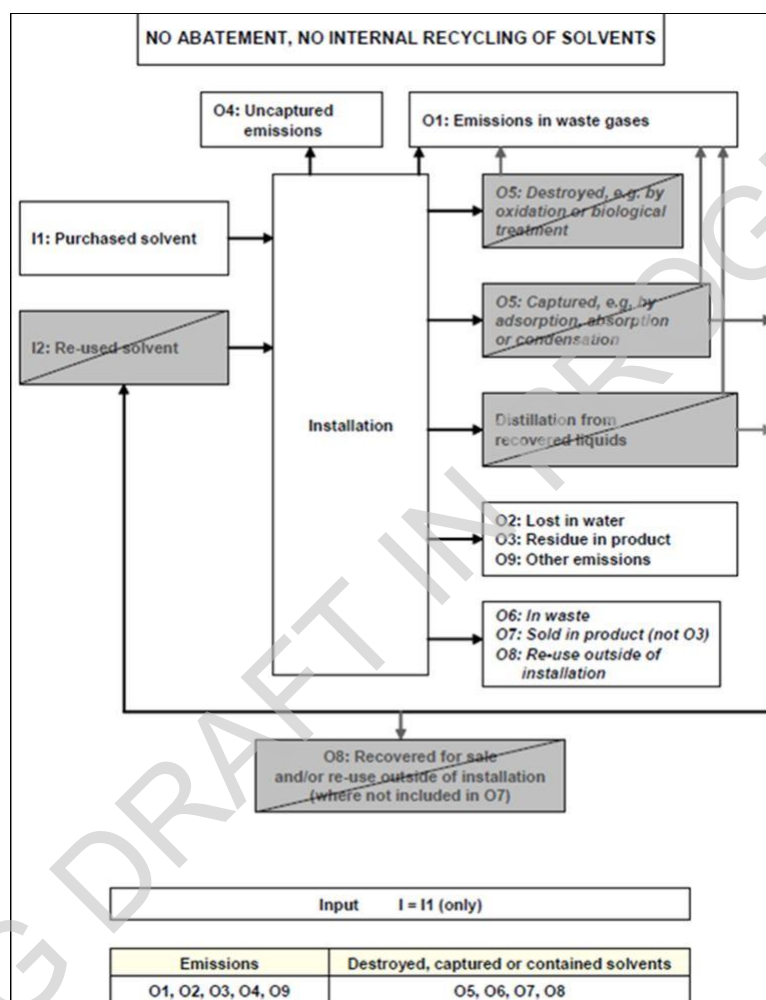


Figure 21.1: No end-of-pipe abatement, and no internal recycling

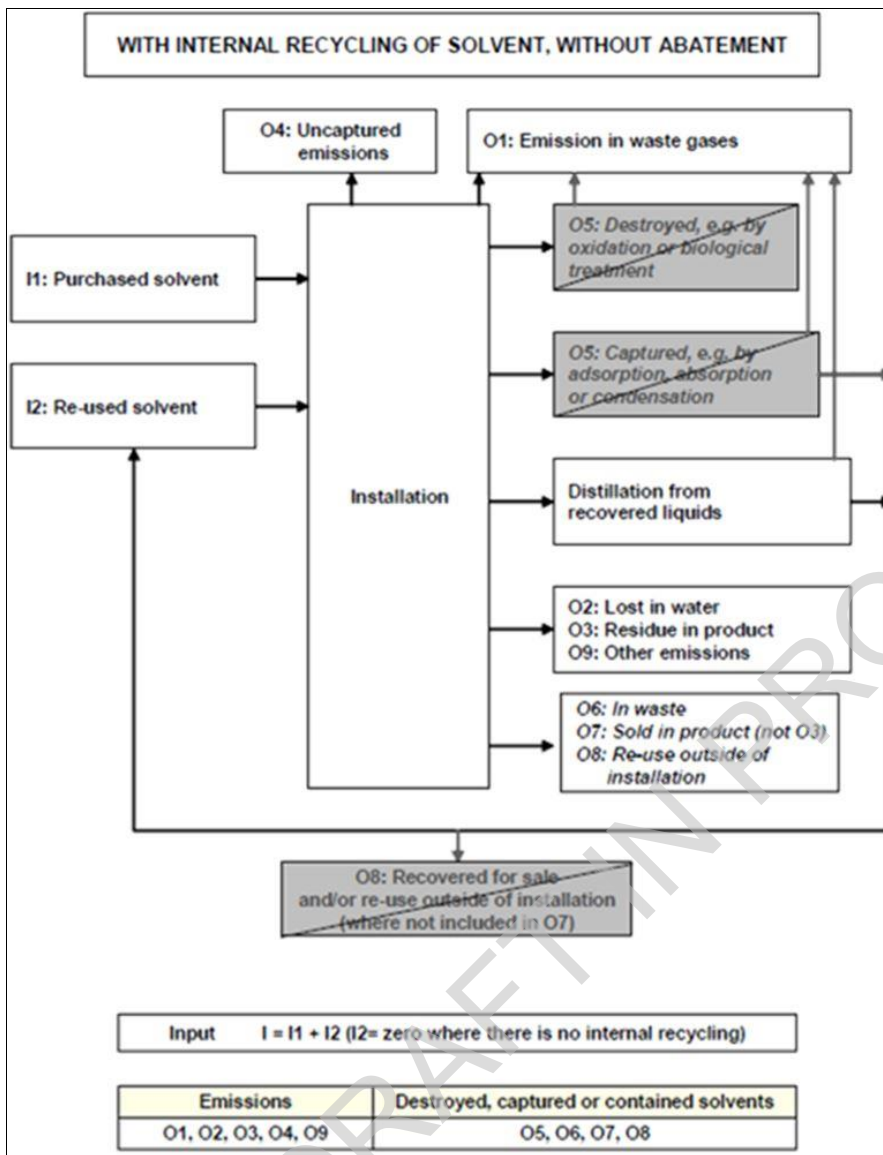


Figure 21.2: No end-of-pipe abatement, but with internal solvent recovery and reuse

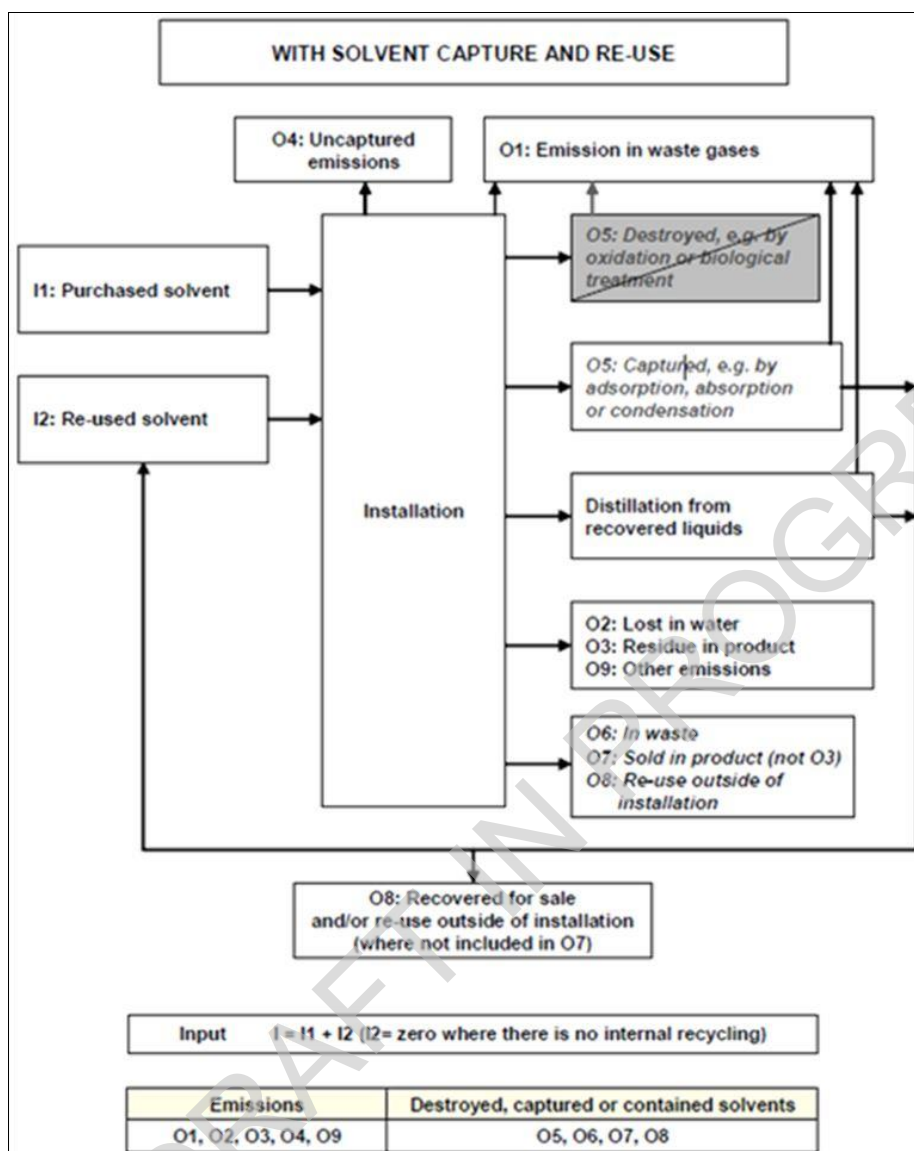


Figure 21.3: With solvent capture and reuse (internally and externally)

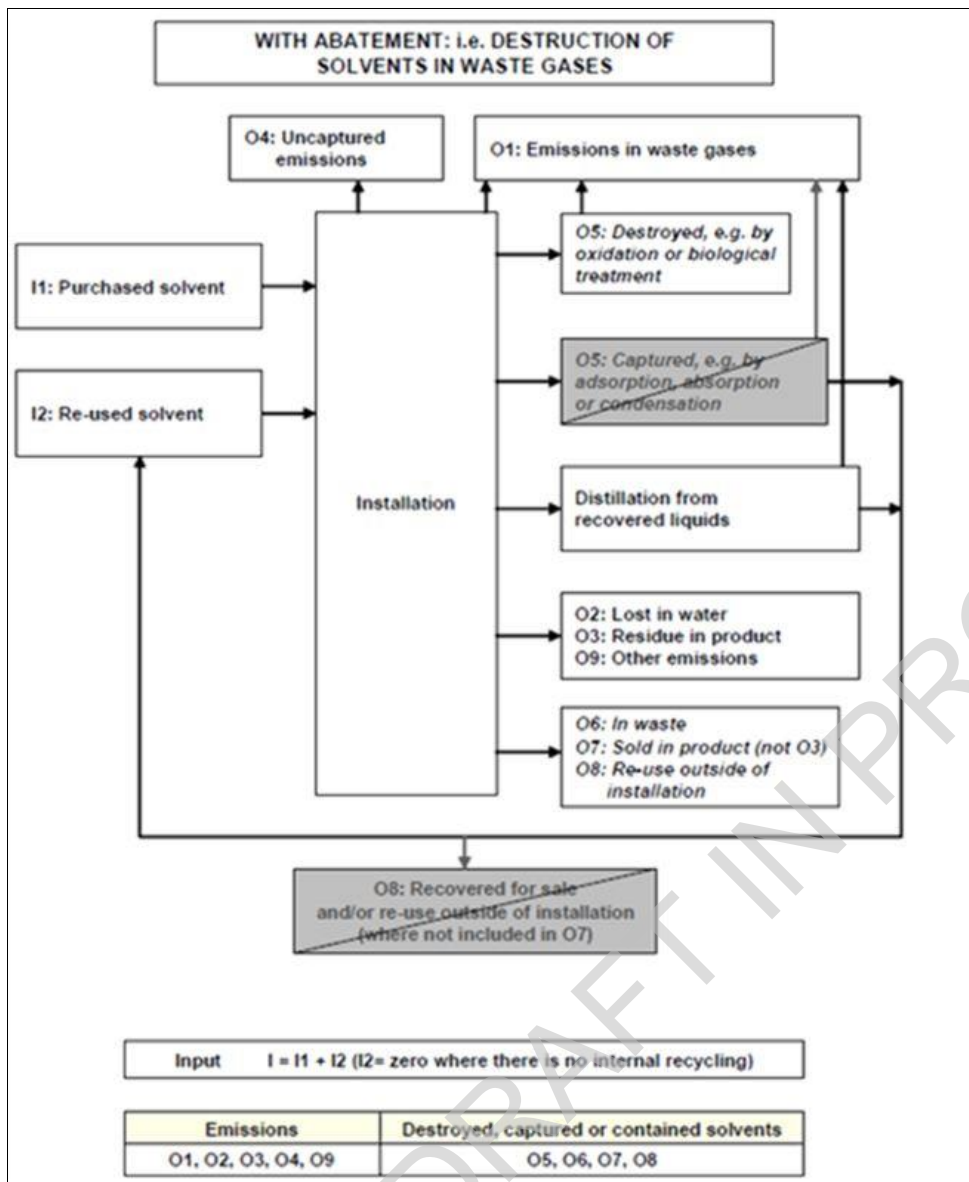


Figure 21.4: Destructive end-of-pipe abatement

## 21.6 Determination of VOC emissions from vehicle paint shops

[159, ACEA, 2006]

*This section will be updated and completed by the ACEA submission: "BAT for solvent mass balances of motor vehicle paint shops" [209, ACEA, 2017] also available on BATIS– WORK IN PROGRESS*

### 21.6.1 Basic principles/overview

1. Limit values of organic substances ( $LV_{VOC}$ ) which are emitted from vehicle paint shops are defined as total emissions of volatile organic compounds – VOC ( $M_{VOC}$ ) of the installation in relation to the surface of the painted vehicles ( $A_{veh}$ ):

$$LV_{VOC} = \frac{m_{VOC}}{A_{veh}} \left[ \frac{\text{g VOC}}{\text{m}^2} \right]$$

Determination of these values means simultaneous determination of the emission mass flow from the paint shop and the surface area of the vehicles to be painted (see Sections and 2.2).

2. Determination of VOC emissions from paint shops by continuous end-of-pipe measurements is not sufficiently accurate, reliable or robust enough for regular monitoring purposes. It fails to take account of potentially significant fugitive emissions and gives poor cost-benefit considering the high capital and operating costs (see Section 21.6.2.1 and 21.6.2.2). The technique is not considered good practice.
3. For regular monitoring of VOC emissions, a mass balance method based on the scheme in the IED should be used. The required accuracy of the determination of different mass flows (see Figure 21.5)
4. Figure 21.5 for the explanation of symbols, which equate to the IED scheme) should follow their relative contribution to the overall result (see Section 2.1.2):
  - VOC input data (I1) must be determined with highest accuracy. This can be achieved by one of the following:
    - direct metering of the consumption of all compounds containing solvent (paint, thinner, etc.)
    - calculation of solvent input using procurement data bases.

If internal recycling of solvent is done, I2 must be determined.

- The amount of destroyed VOC (O5) can be calculated from measuring input and output mass flows of the waste gas treatment unit. From these measurements also:
  - the temperature dependency of the combustion efficiency is derived
  - the carryover factor  $f_c$  is determined. This coefficient describes the amount of VOC released in the spray booth and transferred into the dryer oven with its waste gas treatment unit
  - these measurements must be done once for each spray booth or oven waste gas treatment system (WGT). The combustion efficiency and carryover coefficient must

be recalculated only when the application process, the cabin design or the waste gas extraction and combustion system is changed.

- Performance of the waste gas unit can be monitored by continuous temperature measurement of the combustion. The efficiency of the WGT can be verified by this measurement.
- For given carryover factors  $f_c$  the amount of destroyed VOC can be monitored using consumption data of the spray booth:

$$O5 = (I1 + I2) \times f_c - O1.1$$

- All other mass flows are negligible or small. Single measurement or estimation of these values, to be repeated only after process or design change, is sufficient.

Total emissions into air (E) can be calculated using:

$$E = F + O1$$

where fugitive emissions

$$F = I1 + I2 - O1 - O5 - O6 - O7 - O8$$

$$E = I1 + I2 - O5 - O6 - O7 - O8$$

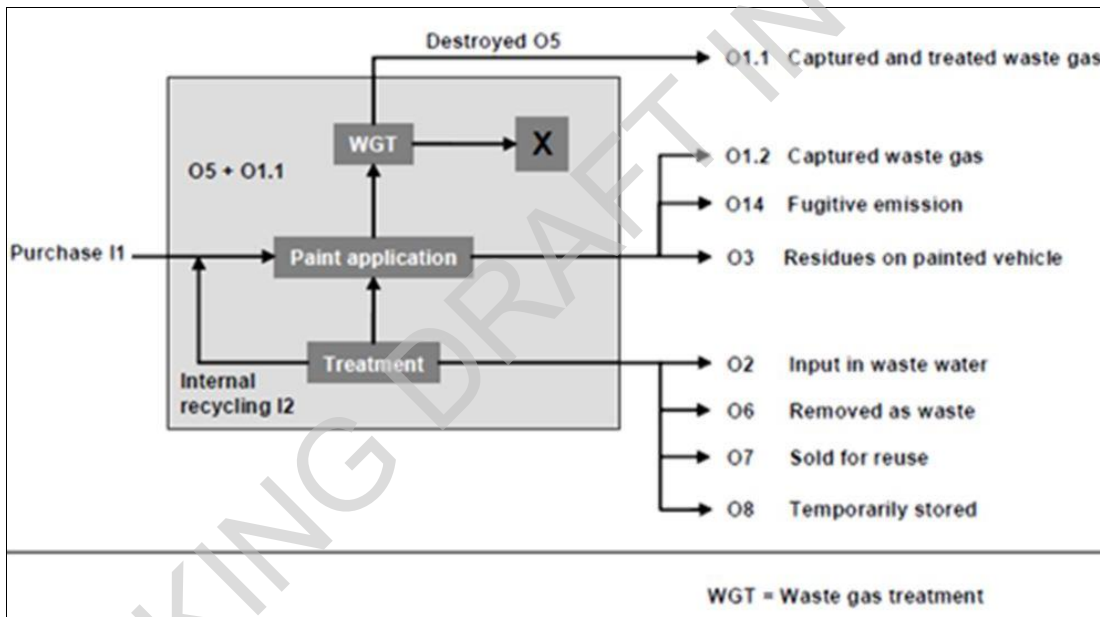


Figure 21.5: Basic input/output mass flows of solvents in a paint shop

5. The surface area  $A_t$  of a body is calculated for each vehicle type  $t$  from:

$$A_t = \frac{2 \times m_t}{b_t \times d_t} \quad [m^2]$$

with

- $m_t$  = total weight of body in white shell
- $b_t$  = average thickness of metal sheet
- $d_t$  = density of metal sheet



Alternative methods (e.g. using CAD data) are also applicable.

6. The total surface  $A_{veh}$  area is obtained from the number  $n$  of the cars which are transferred from the paint shop to the final assembly. This is in accordance with the ‘product’ definition in the IED.

$$A_{veh} = \sum_{t=1}^j A_t \times n_t \quad [m^2]$$

The number of vehicles needs to be determined for each type  $t$ .

7. Due to variations of the production process in time and production constraints (colour and vehicle change, cleaning, breaks...) the time scale for monitoring needs to be long enough. Representative values from mass balance calculations can be obtained only from averaging periods of at least one month. In accordance with the IED, Annex VII(3), solvent management plans, limit values for VOC emissions from vehicle paint shops should be annual mean values.

## 21.6.2 Explanation

### 21.6.2.1 Monitoring of VOC emission mass flows

#### 21.6.2.1.1 End-of-pipe measurements

##### a. Number and location of test points

Correct measurements need long undisturbed measuring sections, which are normally available only in high stacks. All other configurations need a net measurement with several test points in the duct cross-section to average flow- and concentration fluctuations.

Measurements of the cabin effluent stream have to be made in each single duct leaving the cabin. In some paint shops more than 50 stacks are used. If central waste gas ducts are used, these ducts have very large diameters and are heavily obstructed by other pipework and appliances. The installation of measuring points at the correct location is difficult or even impossible, especially if it has to be installed in existing paint shops. In nearly all cases, multiple points would have to be installed (see above).

The waste gas of the dryer ovens is usually treated by some abatement technique. Emissions from waste gas treatment units (WGT) have to be measured in the hot clean air stream.

Depending on the technical design of the installation, fugitive emissions may be significant and have to be assessed to meet the requirements of the IED. By definition, end-of-pipe monitoring does not cover these sources. Direct monitoring of fugitive emissions is not possible or extremely expensive for complex installations such as vehicle manufacture.

**Conclusion:** *To collect emission data by end-of pipe measurements many test points must be installed. Fugitive emissions cannot realistically be measured directly.*

##### b. Measuring principle

Continuous and discontinuous measurements are usually done by the FID (flame ionisation detection) method. A small volume of the waste gas is continuously supplied to the equipment.

Organic compounds are burned in a hydrogen-air flame. The ionisation of organic compounds occurs, giving an electrical current which is measured and which is proportional to the mass flow of the organic compounds in the sample stream.

The output signal of the detector depends on the chemical nature of the compounds, but also on the geometry of the detector and the conditions under which the burner is operated. Regular calibration of the whole system is necessary. The calibration function constitutes a relation between detector signal strength and concentration of propane in the reference gas. The results are given in ppm or ppb equivalent to CH<sub>4</sub>.

Due to its principle, the method continuously determines an index value that responds mainly to the number of C-H bonds in the sample gas volume. The response factor is not constant for all organic compounds but is a unique property of each substance. Therefore only after a second calibration which establishes a correlation between the detector signal (shown in ppm CH<sub>4</sub>) and the concentration of organic compounds in the sample, meaningful concentration values in g VOC/m<sup>3</sup> can be given.

The calibration process has to be repeated in regular intervals.

Compounds with lower volatility may condense in the line of sampling or in the systems of the analyser. It is thus necessary to heat the relevant parts of the system to a temperature of at least 150 °C. This precaution is vital for analysing the waste gases of curing ovens.

**Conclusion:** *The analytical set-up is very demanding and technically difficult for the situations described in Section 21.6.2.1.1(a). Repeated calibration is necessary to adjust the detector signal to the real concentration of VOC in the effluent gas.*

#### c. Representativeness of on-line FID systems

Even though this method can easily be chosen and applied in the case of one organic compound, it becomes extremely difficult and delicate in the case of the car painting processes. Automotive paint systems are very complex formulations with many volatile organic substances. More than 20, very often up to 50 different volatile organic compounds can be found in the effluent air. Moreover, the composition is not constant with time and depends on:

- colour mix in the application cabin (each colour differs in its solvent composition)
- amount of solvent used for cleaning (colour change, etc.)
- kinetics of evaporation from the vehicle surface
- re-evaporation of solvent from water in the venturi scrubber system.

**Conclusion:** *Practically, it is not possible to calibrate an on-line FID monitoring system in such a way that the detector signal gives real values for the actual VOC concentration*

#### d. Cost

The operating expense for continuous measurements is very high. It would be necessary to equip each exhaust stack with an FID analyser, usually with multiple sampling points and therefore sophisticated sampling control and recording. Due to the dimensions of the paint shop, heated sampling lines of up to 20 m length must be installed for each sample point. Each FID analyser must be fed with hydrogen gas, synthetic air and calibration gas. In addition to the VOC measurement O<sub>2</sub> concentration, temperature, humidity and gas velocity must be determined. The equipment also needs daily maintenance to avoid blocking of the air inlet tubes by paint particles. For calibration purposes discontinuous compliance measurements with approved reference methods must be made by verified expert organisations, usually external independent institutions.

**Conclusion:** *The cost for the monitoring of VOC emissions with the end-of-line method is extremely high.*

**e. General conclusion**

The principal drawback for monitoring of VOC emissions with the end-of-line method is that only the emissions from stacks can be measured. The expense is extremely high for this type of industry. Diffuse emissions cannot be measured directly within reasonable means. This type of emission monitoring should be applied only when special operating conditions of an installation, which cannot be covered by calculations, need to be monitored or if other reasons justify intensive monitoring. In the car painting industry, these conditions do not occur.

**21.6.2.1.2 Calculation of solvent mass balances**

**Basic principle**

The IED prescribes a general method for solvent emission monitoring using a solvent mass balance (solvent management plan). This method can be applied with small adjustments for vehicle paint shops as well.

In Figure 21.5, the general scheme of a solvent mass balance is shown. The numbering of the input and output flows is taken from the IED and extended for the purpose of differentiating between waste gas from paint cabins (O1.2) and curing ovens with waste gas treatment (O1.1).

Table 21.9: Input/output flows in vehicle paint shops (according to IED)

No.	Mass flow	Relevance	Comment
I1	Input of organic solvents	High	= <b>100 % (in general)</b> VOC in paints, thinners and spray gun rinsing solvents and general purpose cleaning material
I2	Input of organic solvents from internal recycling	No	= <b>0 % (in general)</b> In some cases solvents are reused after internal purification. If solvent is recycled by external operators, it should be registered under I1
O1	Emissions in waste gases	High	= <b>60 – 95 %</b> Emissions from: <ul style="list-style-type: none"> <li>• application cabins (O1.2) without treatment</li> <li>• residual emissions after waste gas treatment (O1.1) (usually waste gas from curing ovens, sometimes from paint cabins)</li> </ul>
O2	Solvents carried out with waste water	Low	≤ <b>5 %</b> Depends on amount of waste water and solubility of VOC in water
O3	Solvent residues in painted surface of vehicles	No	= <b>0 %</b>
O4	Fugitive emissions	No	≡ <b>0 %</b> Since fugitive emissions cannot be monitored, this mass flow is treated as part of O1.2
O5	Solvents which are captured and destroyed in waste gas treatment systems	High	= <b>10 – 40 %</b> Generally thermal incineration of dryer oven waste gas, sometimes from cabin waste gas as well.
O6	Output of solvent as waste	Yes	= <b>5 – 10 %</b> <ul style="list-style-type: none"> <li>• as mixture of paint and thinner</li> <li>• as residue in paint sludge</li> </ul>
O7	Sold as product	No	= <b>0 %</b>
O8	Solvents recovered for reuse or temporarily stored	Low	≈ <b>0 % (usually)</b> (Solvents, paints, which are already counted as input but not used during the reporting period)
O9	Any other output	No	= <b>0 %</b>

Total emissions into air (E) can be calculated for paint shops using the indirect method of the IED

$$E = F + O1$$

with

$$F = I1 + I2 - O1 - O5 - O6 - O7 - O8 \text{ (fugitive emission)}$$

$$E = I1 + I2 - O5 - O6 - O7 - O8$$

Under normal operating conditions, this equation simplifies to:

$$E = I1 - O5 - O6$$

The advantage of the indirect method is that direct monitoring of O1 (emissions in waste gases) and O4 (fugitive emissions) is not necessary. Since O1 is the largest flow of all output flows, any measurement uncertainties of O1 have a very large impact on the overall monitoring

accuracy. Generally, the direct method is only applicable if fugitive emissions (O4) can be definitely excluded.

**Conclusion:** *The mass balance method is the most appropriate way for monitoring VOC emissions into air. It takes account of any fugitive emissions, as required by the IED. Expensive and unreliable direct end-of-pipe measurements are substituted by a set of measurements and calculations of the residual mass flows. The result is comprehensive, robust, sufficiently precise and is obtained with less expense.*

### 21.6.2.1.3 Methods for the determination of specific mass flows

#### I1 Solvent input

(a) Direct metering of the consumption of all compounds containing solvent (paint thinner, etc.).

(b) Calculation of solvent input using procurement databases. The amount of rejected material must be identified and considered.

For method (a), control devices to monitor the filling status of the storage tanks must be installed and online data processing of the signals is recommended. Consumption data can be integrated into the existing production management IT systems and are also available for performance optimisation activities. For method (b), data from financial data bases can be used.

In both cases knowledge about the solvent content in the paints and other material is crucial and must be requested from the supplier.

#### O2 Solvent carried out with waste water

Not only paint particles but also volatile organic compounds are dissolved in the water reservoir of the venturi scrubber. Waste water is discharged from this system with solvent concentrations up to the solubility equilibrium. The solvent management plan of the IED presumes that this solvent will be completely emitted from the sewerage system or the waste water treatment installation. Since O2 is a rather small mass flow compared to O1 or O5, it is sufficient to treat it as a constant or a function of the waste water volume.

#### O5 Solvent captured and destroyed by waste gas treatment

The mass flow O5 is the residue of the solvent which is emitted from any sort of waste gas treatment into the air (O1.1, VOC in captured and treated waste gas) and the input of solvent within the raw gas flow (O5<sub>in</sub>) into this equipment.

$$O5 = O5_{in} - O1.1$$

Volatile organic compounds in the waste gas flow of waste gas treatment installations (O1.1) can be measured by continuous or discontinuous methods. According to IED a limit values of 50 mg C<sub>tot</sub>/m<sup>3</sup> must be regarded for these emissions after air treatment installations<sup>32</sup>.

Air treatment systems efficiency is controlled via temperature monitoring. The combustion temperature, which guarantees observance of the limit values under all operational conditions, is determined by calibration measurements.

The mass flow of VOCs from each application zone to the emission abatement equipment is proportional to the solvent consumption of the painting process in the cabin. Therefore (if I2=0)

$$O5_{in} = I1 * f_c$$

<sup>32</sup> A limit value of 50 mg C<sub>tot</sub>/m<sup>3</sup> corresponds to approximately 70 mg VOC/m<sup>3</sup>.

The carryover factor  $f_c$  describes the ratio of solvent consumption in the application zone to the VOC input into the waste gas treatment equipment of the dryer oven. It is constant within the range of solvent consumption for a given paint application process and cabin geometry. This factor should be recalculated only when the application process, material technology or the cabin design (or related extraction system, etc.) is changed.

#### O6: Organic solvents disposed of as waste

The largest mass flow in this category are separately captured solvents from purging and cleaning processes (colour change, purging of the ring pipe system, general cleaning). Monitoring is done by measuring the flow volume in the tank inlets or from extracting data from transport documents. Generally, recovered solvents contain considerable amounts of paint, therefore determination of the VOC concentration may be necessary.

Solvents are also carried out with paint sludge. Concentrations of VOC in paint sludge should be established and verified as necessary.

**Conclusion:** *Most of the mass flow data that need to be established are constant or depend on material consumption and other easily accessible parameters.*

### 21.6.2.2 Determination of the surface area throughput

#### 21.6.2.2.1 Vehicle surface area

According to IED, the surface area dealt with is defined as follows: 'the surface area calculated from the total electrophoretic coating area, and the surface area of any parts that might be added in successive phases of the coating process which are coated with the same coatings as those used for the product in question, or the total surface area of the product coated in the installation.'

The surface of the electrophoretic (e-coat) coating area is calculated using the formula:

$$A_t = \frac{2 \times m_t}{b_t \times d_t} \quad [m^2]$$

with

$m_t$  = total weight of body in white shell

$b_t$  = average thickness of metal sheet

$d_t$  = density of metal sheet

This method shall also be applied for other coated parts. Alternative methods (e.g. using CAD data) are also applicable.

The index t indicates that different types of bodies have different surface areas:

$$A_{veh} = \sum_{t=1}^j A_t \times n_t \quad [m^2]$$

**Conclusion:** *The correct determination of the e-coat area for each car model is very important. The procedure should be documented and operators must be aware that all relevant data might be checked by the competent authority.*

### 21.6.2.2.2 Number of vehicles per time period

The mass balance method – on which VOC emissions monitoring in the automotive industry is based, according to the Solvent Emissions Directive 99/13/CE – requires the calculation of the total area of bodies painted. The number of cars that are taken into account are the number of cars coated in the paint shop and delivered (as ‘product’ of the paint process) to the final assembly line.

Therefore vehicles that must be painted a second time (re-runs) are not counted twice and the additional solvent emissions caused by the repainting are assigned to the number of the original vehicles. Likewise bodies which are scrapped are not counted.

*Conclusion: Vehicle production data as described above are available from production control systems, therefore no additional expense is incurred by the emission control requirements.*

### 21.6.2.3 Time scale for mass balance representativeness

#### 21.6.2.3.1 Limit values based on small averaging periods

It should be kept in mind that for technical as well as for practical reasons, there is always a time gap between measurement or calculation of solvent emissions and determination of the number of vehicles as a prerequisite for the calculation of the reference surface area. Therefore, a limit value with low averaging time cannot be adequately monitored.

All paint shops are operated with venturi systems to remove paint particles from the effluent air. Solvents are dissolved in the water (especially with waterborne paints) and repeatedly pumped through the system. These dissolved solvents lead to residual VOC emissions even if no vehicle is painted and only the clean air from the cabin conditioning system is blown through the venturi system.

Long periods exist where emissions take place but no or only a limited number of vehicles are painted. This is because of production breaks, periodic cleaning of cabins and application equipment or start of production after weekend time outs. The emission value, defined as ratio of emission to the surface area goes up to high or even infinite values, even if the absolute amount of solvent emissions is rather small.

A definition of the emission limit value as hourly, daily or shift mean would lead to strongly fluctuating values because of these effects. Emission values will very often formally exceed limit values even if the mass flow of solvent in terms of grams is very small (as the  $m^2$  value is low or zero). The calculation of solvent emission data in  $g/m^2$  for time scales smaller than one month would not give representative values.

*Conclusion: Emission limit values, based on short averaging periods cannot be adequately monitored. As the emission values are a ratio of mass flow of VOC to the production rate, large fluctuations may be recorded which do not give meaningful information about the environmental impact.*

#### 21.6.2.3.2 Limit value based on annual mean value

A reference period of one year corresponds very well with the character of this limit value as a parameter which defines the environmental quality of the paint process. In fact, the solvent balance of the Solvent Emissions Directive requires data on an annual mean level. All typical

production situations are averaged out and the overall performance of the paint shop is monitored.

There are no toxicological reasons to limit, and therefore monitor, short time fluctuations of the VOC emission.

**Conclusion:** *The annual mean as the reference period for the emission limit of vehicle paint shops is appropriate.*

## **Some Solvent Emissions Directive limit values**

Because of the complexity of the Solvent Emissions Directive [73, COM, 1999], and ascertaining that activities in this Directive apply to industries in this reference document, some data for some of the industries are given below:

### **SED Activity 7, Coil coating:**

The SED limit values are:

- reducing VOC emissions to  $50 \text{ mgC/m}^3$  for waste gas emissions or  $150 \text{ mgC/m}^3$  where solvents are recovered from waste gases and:
  - for new plants 5 % for diffuse emissions
  - for existing plants 10 % for diffuse emissions
- if using the reduction scheme, diminishing the overall emissions:
  - for new plants to 0.3 kg VOC per kg consumption of non-volatiles
  - for existing plants to 0.45 kg VOC per kg solids.

### **SED Activity 8, Other coating including metal, plastic, textile, etc.**

The SED limit values are:

- reducing VOC emissions to  $50 \text{ mgC/m}^3$  for drying and  $75 \text{ mgC/m}^3$  for coating application in waste gases and to 20 % of solvent consumption for diffuse emissions, or
- if using the reduction scheme, diminishing the overall emissions to 0.375 kg VOC per kg consumption of non-volatiles.

### **Metal packaging (also Activity 8):**

In the SED, two compliance routes are available: emission limit values and solvent reduction schemes. Draw and wall iron (DWI) cans processes are capable of using replacement materials substitution to achieve compliance via solvent reduction schemes [38, TWG, 2004].

The SED limit values are:

- reducing VOC emissions to  $50 \text{ mgC/m}^3$  for drying and  $75 \text{ mgC/m}^3$  for coating application in waste gases and to 20 % of solvent consumption for diffuse emissions, or
- if using the reduction scheme,:
  - for non food applications, diminishing the overall emissions to 0.375 kg VOC per kg consumption of non-volatiles
  - for coatings in contact with food, diminishing the overall emissions to 1.165 kg VOCs/kg solids.

### **SED Activity 10, Wood coating**

The SED limit values are:

- reducing VOC emissions to  $50 \text{ mgC/m}^3$  for drying and  $75 \text{ mgC/m}^3$  for coating application in waste gases and to 20 % of solvent consumption for diffuse emissions, or



- 
- ~~if using the reduction scheme, diminishing the overall emissions to 1.0 kg VOC per kg consumption of non-volatiles.~~

**SED Activity 12, Wood preservation**

The SED limit values are:

- ~~reducing VOC emissions to 100 mgC/m<sup>3</sup> in waste gases (not with creosote) and to 45 % of solvent consumption for diffuse emissions, or~~
- ~~11 kg/m<sup>3</sup> for total VOC emissions~~
- ~~if using the reduction scheme, diminishing the overall emissions to 0.75kg VOC per kg consumption of non-volatiles.~~

WORKING DRAFT IN PROGRESS

## 21.7 Calculation of effective POCP

See Section 17.6.2.

*This section will be updated and completed at a later stage*  
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**References:** Swan Eco-label (the Swan Eco label: labelling of car and boat care products, [www.Svanen.nu](http://www.Svanen.nu).) [117, Lemoine, 2006] [118, Tempany and Lemoine, 2006].

The POCP concept (or other reactivity scales, such as MIR) is based on the assumption that 100 per cent of the solvent evaporates directly on exposure to air. This does not hold for several chemical substances because the rate of evaporation varies between different substances. In order to be able to assess the ozone creation of the actual quantity that ends up in the atmosphere (within a reasonable time), the POCP of a substance should be weighted against its relative rate of evaporation (RA). RA is based on the substance's vapour pressure and diffusion in air, and is calculated by dividing the rate of evaporation for the substance in question by the rate of evaporation for a reference substance. Butyl acetate is used as the reference substance.

However, the calculation is long and for several substances in a mixture in differing conditions, can be tedious (see calculation, below)

An approximate surrogate is to use vapour pressure multiplied by the POCP (or other reactivity scale). To differentiate from the effective ozone creation potential (APOCP<sub>e</sub>, see below) call this the POFP, the Photochemical Ozone-Forming Product where OFP is the Photochemical Ozone Forming Potential, usually POCP:

$$\text{POFP} = (\text{Vapour pressure}) \times (\text{OFP})$$

and

$$\sum_1^n [\text{POFP}_{\text{total}}]_{\text{total}} = \sum [\text{POFP}]_1 + [\text{POFP}]_2 + \dots [\text{POFP}]_n$$

where:

[POFP]<sub>1</sub> is the concentration (or mass or percentage) of Substance 1 with a Photochemical Ozone-Forming Ratio 1 = Concentration<sub>1</sub> x (Vapour pressure)<sub>1</sub> x (OFP)<sub>1</sub>, etc.

[POFP<sub>total</sub>]<sub>total</sub> is the total Photochemical Ozone-Forming Product for n substances in given mixture (or single substance where n = 1)

Where the concentration is expressed as wt-%, POFP<sub>total</sub> must be multiplied by 100. To arrive at a suitable scale for comparisons, the parameters are best expressed as:

- vapour pressure (VP) in kPa (range approximately 0.001 to 50 kPa). The VPs for more than one solvent should all be expressed at the same temperature
- concentration as a percentage (range 0 – 100)
- if POCP is the unit, use a scale of ethylene = 100, then the range is about 10 to 140.

Examples of calculations:

**Table 21.10: Example 1 of an effective POCP calculation**

Formulation 1				
	* Xi (%)	VP (KPa)**	POCP	POFP value
Xylene	40	0.87	110	3828
POFP <sub>total</sub>				3828
* (Xi) concentration of the substance in the formulation)				
** At 20 °C				

Table 21.11: Example 2 of an effective POCP calculation

Formulation 2				
	* Xi (%)	VP (KPa)**	POCP	POFP value
n-butyl acetate	20	1.529	27	826
Dearomatised white spirit	20	0.46	41	377
[POFP <sub>total</sub> ] <sub>total</sub>				1203
* (Xi) concentration of the substance in the formulation				
** At 20 °C				

**Calculation of relative rate of evaporation (RA) and APOCP<sub>e</sub>**  
(from the Swan Eco label: labelling of car and boat care products):

The rate of evaporation (F) of a substance can be calculated according to Fick's 1st law:

$$F = D \times (dC/dZ) \quad (I)$$

where:

- D is the diffusion constant of the substance in air
- dC/dZ is the concentration gradient from an area where the substance exists to free air, and can be calculated using the general gas law as follows:

$$dC/dZ = (P \times M_w)/(RT \times 10^6) \quad (II)$$

where:

- R = 8.32 J K<sup>-1</sup> mol<sup>-1</sup>
- T = absolute temperature
- dZ = 1 cm

If the diffusion constant is given in cm<sup>2</sup> s<sup>-1</sup>, F may be expressed as g cm<sup>-2</sup> s<sup>-1</sup>.

$$RA_i = F_i / F_{\text{butyl acetate}}$$

According to equations I and II, butyl acetate has a rate of evaporation (F) of 4 x 10<sup>-6</sup> g cm<sup>-2</sup> s<sup>-1</sup> at 20 °C.

Table 21.12: Examples of relative rates of evaporation (RA) for a selection of VOCs

Substance	RA
2-propylene glycol-1-methyl ether	0.84
Isopropanol	2.5
Butyl acetate (reference)	1.0

Multiplying the absolute ozone creation potential of a substance by its relative rate of evaporation (RA) produces a measure of the effective ozone creation potential, APOCP<sub>e</sub>:

$$APOCP_{e,i} = APOCP_i \times RA_i$$

Example calculation. Determination of APOCP<sub>e, isopropanol</sub> in environment A

$$APOCP_{e, isopropanol} = 0.06 \times 2.5 = 0.15$$

**Table 21.13: Examples of APOCP<sub>e</sub> for a selection of VOCs and a reference VOC in the five different environments A, B, C, D and E**

Substance	A	B	C	D	E
2-propylene glycol-1-methyl ether	0.08	0.18	0.12	0.18	0.52
Isopropanol	0.15	0.38	0.25	0.4	1.2
VOC reference	0.11	0.27	0.17	0.27	0.84

APOCP is the same number as POCP in the previous calculation.

WORKING DRAFT IN PROGRESS

## 21.8 Marginal social costs of climate change

*This section will be updated and completed at a later stage*  
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A recent report [66, AEA, et al., 2005] reviews current thinking on the social costs of climate change expressed as EUR/t CO<sub>2</sub>. A recent review is quoted giving a mean of EUR 25/t CO<sub>2</sub> with a 95 %ile of 96/t CO<sub>2</sub>. Other workers are citing figures in the area EUR <12 to <20/t CO<sub>2</sub>. The report shows that these figures are based on data for market effects and ignore wider social implications and catastrophic effects from higher climate temperature increases: these are harder to define and agree costs.

Different stabilisation scenarios have differing costs:

- low rate of increase of climate temperature: EUR <15/t CO<sub>2</sub>
- high rate of increase of climate temperature: EUR 30 – 140/t CO<sub>2</sub>.

However, the report [66, AEA, et al., 2005] looked at these areas and estimated figures for 2002 of:

- a lower bound of EUR 15/t CO<sub>2</sub>
- a central illustrative estimate of EUR 20 – 25/t CO<sub>2</sub>, rising to EUR 30/t CO<sub>2</sub> by 2020
- upper central estimate of EUR 80/t CO<sub>2</sub>.

From these, a central working estimate of EUR 30/t CO<sub>2</sub> has been derived for this document, to compare with marginal damages for VOC per tonne emission from the cost benefit assessment for CAFE (see the ECM REF [50, COM, 2005]).

This is an area of major political interest and continuing development of the economics. For example, see Stern Review of Environmental Economics, [124, Stern, 2006]. From this interest, the tendency may be towards including the wider social implications and catastrophic effects that are associated with climate change, but not with other environmental impacts (such as those associated with VOC, where the marginal social costs fully include key impacts, mainly health). These factors significantly increase the social costs per t CO<sub>2</sub>.

## 21.9 Removal efficiency of waste gas treatment techniques

[97, TWG, 2006] [131, Verspoor and TWG, 2006]

*This section will be updated and completed at a later stage –  
WORK IN PROGRESS*

### End-of-pipe techniques: Descriptions and considerations for applicability

The descriptions and considerations for applicability below are intended as an overview only. See the relevant sections in Chapter 20 of this document for additional information. The information in this annex on its own cannot serve as the basis for the selection of a suitable abatement technique.

**Table 21.14: Waste gas abatement techniques**

End-of-pipe technique and description	Conditions for applicability	Applicable:
<p><b>Thermal oxidation</b> Waste gases are heated by burning natural gas. There is no attempt at heat recovery for a reduction of energy consumption</p>	<p>The simplest oxidation technique with the lowest capital investment Autothermic operation only at concentration levels over 25% LEL. Lowest electrical energy consumption for the main fan. Highest gas relative consumption. As the simplest technique, has relatively the lowest maintenance and least downtime. Rapid start-up (0.5 – 1 h), but requires a stable operating temperature. Non-organic dust needs to be removed (to &lt;3 mg/m<sup>3</sup>) before the oxidation unit, although this technique is more tolerant of dust than others</p>	<p>For intermittent use (a few days a week; very variable airflows; one shift system, etc.) Where the capital costs are much more relevant than operational costs or in combination with other abatement technologies for multi-purpose units or for air volumes &lt;2000 m<sup>3</sup>/h For concentration ranges between 5 and 16 g/m<sup>3</sup>, high inlet temperatures of the waste gas and in situations where gas flow and solvent concentrations are relatively constant. Operation at concentration levels above LEL is also possible</p>
<p><b>Recuperative oxidation</b> Similar to thermal oxidation but with a heat exchanger that preheats the incoming waste gases with the heat of the exhaust gases. Reduces gas consumption, but the heat exchanger requires a higher investment</p>	<p>With a heat exchanger of maximum efficiency (about 76 %), autothermic operations are possible at solvent concentrations approaching 10 g/m<sup>3</sup> (ethyl acetate or ethanol) or more. Autothermic concentration depends on the caloric value of the solvent. Electrical energy consumption for the main fan is higher than in the case of thermal oxidation. Gas consumption is lower. A simple oxidation technique, but with a relatively high investment due to the large steel content. Almost immediate start-up (0.5 – 1 h). Removal efficiency is restricted by the maximum operating temperature which is determined by the mechanical integrity of the heat exchanger. The heat exchanger has a limited lifetime and requires substantial maintenance due to corrosion and thermal stress. Heat</p>	<p>For intermittent use (one or two shift systems), but where the reduction of gas consumption warrants additional capital cost and electrical energy. Where autothermic operation is possible, but excess energy cannot be used in the installation as an alternative for regenerative oxidation</p>

End-of-pipe technique and description	Conditions for applicability	Applicable:
	<p>exchangers may easily be blocked by accumulation of dust in the tubes, and efficiency will be reduced due to the partial fouling, increasing investment and running costs.</p> <p>However, the technique is more tolerant of dust than others, and there are techniques for clearing blockages (air blow, chain cleaning, ball drop, etc.).</p>	
<p><b>Catalytic oxidation</b> Oxidation temperatures are lower, at some 280 – 450 °C (instead of some 800 °C) Often equipped with a heat exchanger. Reduces gas consumption, but catalysts and heat exchangers lead to a higher investment. Catalyst may need maintenance and occasional replacement which add to the operational cost and downtime.</p>	<p>When equipped with an efficient heat exchanger (maximum possible some 87 %), autothermic operations are possible at solvent concentrations of some 5 g/m<sup>3</sup> or over (depending on the calorific value of the solvent). The maximum possible temperature of the catalyst limits the inlet concentration to some 8 g/m<sup>3</sup> Electrical energy consumption for the main fan is higher than in the case of thermal oxidation. With solvent concentrations below 25 % LEL, the gas consumption will be lower than in the case of recuperative oxidation. The catalyst makes this a less simple oxidation technique, but still with a relatively low investment. Almost immediate start-up (1 h to preheat the catalyst), but shutting down too frequently may damage the catalyst carrier. Catalyst adds to the need for maintenance and increases downtime. Some solvents or dust particles poison the catalyst and lead to early replacement of the expensive catalyst. Catalyst and carrier need to be adapted to waste gas composition, required temperature and expected removal efficiency. A used catalyst may need to be disposed of as hazardous waste, although the catalyst material can often be recycled. Very sensitive to the presence of dust and droplets in the waste gases. Sensitive to changes in the inlet concentration</p>	<p>Used only where all solvents that are to be oxidised are known not to poison the catalyst and where the inlet temperature is not too high for the catalyst. Where autothermic operation is possible, but excess energy cannot be used in the installation as an alternative for regenerative oxidation.</p>
<p><b>Regenerative oxidation: 2 beds</b> The oxidising chamber is situated between two ceramic beds. The waste gas passes through one bed before entering the oxidising chamber and leaves through the other. The direction of waste gas flow is alternated every 1 to 5 minutes. One bed preheats the waste gases; the other accumulates the heat from the exhaust.</p>	<p>With a high heat exchanger efficiency (maximum possible 96 %), autothermic operations are possible from solvent concentrations of 2 g/m<sup>3</sup> and over (depending on the calorific value of the solvent, e.g. ethyl acetate 2.2 g/m<sup>3</sup>). Preheating after periods of standstill may, however, account for considerable gas consumption. Electrical energy consumption for the main fan is higher than in the case of other oxidisers because of the high pressure drop in the ceramic beds. Where the solvent concentration in waste gases is higher than the autothermic</p>	<p>Specifically suitable in continuous or near continuous operations where most of the time the solvent concentrations in the waste gases are over the autothermic concentration and the solvent concentrations do not vary significantly</p>

End-of-pipe technique and description	Conditions for applicability	Applicable:
<p>During the changeover solvent-laden waste gases are emitted for a few seconds.</p> <p>Reduces fuel consumption drastically. Increases the need for electrical energy due to the higher air resistance in the ceramic beds</p>	<p>concentration, excess heat is produced. This may be recovered.</p> <p>Where excess heat is not permanently recovered and the concentrations are variable, the efficiency of the heat exchanger may need to be reduced to prevent overheating of the ceramic beds when high concentrations occur. This leads to a higher autothermic concentration and the need for adding natural gas in periods of low solvent concentrations.</p> <p>The complicated sensors and large valves necessary to repeatedly change the direction of the airflow mean complex equipment and the need for skilled personnel.</p> <p>Higher maintenance costs and more downtime than other oxidation techniques. Every one or two years there is a need for 2 to 3 days downtime for maintenance.</p> <p>Needs preheating before start up since the ceramic beds cool down during standstill. (After 36 hours of standstill, 1 to 2 hours are needed for preheating)</p> <p>Removal efficiency is a few per cent lower than that of the 3 bed system (see below) due to emissions during changeover of the direction of the waste gas stream.</p> <p>Where EoP emission limits expressed in mgC/m<sup>3</sup> averaged over a short period of time apply, the emissions during changeover of the direction of the waste gas stream may lead to an average outlet concentration that exceeds the limit values if the inlet concentration is higher than about 3g/m<sup>3</sup>.</p> <p>The regenerator blocks rapidly with dust. It is possible to run with some low dust concentrations, but the regenerative beds need a different structure (structured packing (honeycomb instead of saddles) with different cost and efficiency</p>	
<p><b>Regenerative oxidation: 3 beds</b></p> <p>In principle the same as the 2 bed system. The third bed serves to avoid the emission of solvent laden air during the change of the direction of the waste gas flow</p>	<p>(Relative to the 2 bed system).</p> <p>Investment some 25 % higher than a 2 bed system.</p> <p>Lower emissions.</p> <p>Higher preheating cost.</p> <p>Some 10 % higher electricity consumption due to larger fan for purging purposes</p> <p>Removal efficiency a few per cent higher than that of the 2 bed system due to the prevention of emissions during changeover of the direction of the waste gas stream.</p> <p>Online burnout possible for removing sticky particles</p>	<p>(Relative to the 2 bed system)</p> <p>Most suitable for concentrations from 1 – 12g/m<sup>3</sup>. especially if there is a variation in the concentration over the production time.</p> <p>Most suitable in large continuous operations with solvent concentrations in waste gases well above autothermic concentration.</p> <p>Where the resulting emission reduction warrants the additional investment and operational cost</p>



End-of-pipe technique and description	Conditions for applicability	Applicable:
<b>Other oxidation techniques</b> (Not included in calculations of removal efficiency)		
<p><b>Process heater</b> <i>ESVOC propose deletion.</i> <i>EIPPCB –according to questionnaires used in some plants</i></p> <p>The waste gases to be treated are sent to an existing heater (e.g. boiler) as combustion air and complementary fuel</p>	<p>A suitable heater must be available and must be operating and able to receive all the waste gases at times when they are produced</p>	
<p><b>Flameless oxidiser</b> Packed bed oxidiser in which the front of combustion is kept at a predetermined position in the ceramic packing</p>	<p>Intermediate system between thermal and regenerative oxidiser. Low fuel requirements when idle. Combustion temperature relatively low (800 – 850 °C). Sensitive to the presence of dust</p>	
<p><b>One bed regenerative oxidisers</b> Direction of the waste gas flow alternates over one bed instead of two or three</p>	<p>Generally low capacity systems</p>	
<b>Adsorption (to a solid)</b>		
<p><b>Regenerative carbon adsorption</b> The low temperature waste gases are led through a bed of activated carbon. The solvent adsorbs to the activated carbon. When the carbon is saturated the waste gas flow is switched to a second carbon bed. The saturated bed is desorbed through heating. The heat releases the solvents from the carbon in such a high concentration that it allows condensation of these solvents</p>	<p>Desorption must be done in an atmosphere with little or no oxygen. Steam, nitrogen or oxygen-free hot air may be used. After condensation of the solvent, complex techniques may be necessary to make the recovered solvents ready for reuse. These techniques depend on the solvent recovered.</p> <p>Some examples: In the case of toluene and xylene, desorption is done with steam and simple condensation will suffice. In the case of ethyl acetate, desorption is done with nitrogen. Dewatering with molecular sieves and several subsequent distillation steps are necessary to remove side products and secondary solvents such as acetic acid, traces of ethanol and low volatility solvents.</p> <p>Since the adsorption characteristics of solvents differ enormously, the size of the adsorbers (and therefore not only the investment but also the energy and inert gas consumption) is very much determined by the kind of solvent. (Examples: Toluene and xylene need relatively ‘small’ adsorbers. Ethanol needs a 25 % larger adsorber than ethyl acetate)</p> <p>Some solvents may react with the activated carbon and cause fire. MEK is one of these, but techniques exist to prevent these reactions and recover MEK safely.</p> <p>Some low volatility solvents may adhere to the activated carbon permanently and quickly reduce the adsorption capacity with</p>	<p>Only to be considered when the recovered solvent can be reused in the installation or be sold against the market value of ‘fresh’ solvents. (The sale of recovered solvent brings no more than 50 % of its original price). Where several hundred tonnes of toluene or xylene are used as the only solvent this technique can always be seriously considered. With other solvents higher annual quantities are necessary to make this a viable option. Especially where there are mixtures of several different solvents, numerous complications may need to be solved before this technique can be used successfully. However, technical solutions exist for most of these practical problems. The end result may be too complicated and expensive</p>

End-of-pipe technique and description	Conditions for applicability	Applicable:
	<p>early replacement of the activated carbon as a result.</p> <p>Activated carbon also adsorbs water effectively. Waste gas streams with a high moisture content are therefore not suitable. Investment and operational cost are considerably higher than in the case of oxidation. This is more evident where the solvent loads are below 1000 tonnes per year.</p> <p>Alternatives with moving carbon beds exist, but are not commonly used.</p> <p>Electrical energy consumption for the main fan is higher than in the case of oxidisers because of the higher resistance of the beds of activated carbon. High displacement with low airspeeds necessary to prevent blowing out of the activated carbon.</p> <p>The complex equipment requires specifically trained technical personnel. Very reliable operations and very little downtime are the norm.</p> <p>The high cost in comparison to oxidation and with the low market value of recovered solvents necessitates the reuse of the solvents in the same installation in order to make solvent recovery a viable option.</p> <p>Breakeven point between oxidation and recovery evidently depends on the price of the solvent recovered and the techniques necessary. For toluene and xylene, recovery may be cheaper than oxidation starting at a solvent consumption of 100 t/yr. For ethyl acetate, MEK and ethanol, breakeven with oxidation was calculated to be possible starting at approximately 500 to 1000 tonnes per year.</p> <p>Does not work with high inorganic dust concentrations</p>	
<p><b>Polymer adsorption</b></p> <p>The low temperature waste gases are lead through a moving bed of grains of a special polymer. The solvent adsorbs to the polymer. The saturated polymer is desorbed through heating. The heat releases the solvents from the polymer in such a high concentration that it allows condensation of these solvents</p>	<p>Desorption is done with hot air. The concentrations are above the higher explosion limit in order to prevent accidents.</p> <p>After condensation of the solvent, complex techniques may be necessary to make the recovered solvents ready for reuse. These techniques depend on the solvent recovered. Since the adsorption characteristics of solvents differ enormously, the amount of polymer necessary is very much determined by the kind of solvent. Since the polymer is the most costly part of the equipment (10 to 20 times the cost of activated carbon). this technique is known to be suitable for only very few solvents.</p> <p>Since the polymers do not adsorb water, the system can be used for waste gases with high moisture content. Also no dehydration</p>	<p>No examples of successful application in industries in the scope of this document are known</p>

End-of-pipe technique and description	Conditions for applicability	Applicable:
	<p>of the recovered solvent is necessary. The equipment is very simple. High displacement fans with low airspeeds are necessary to prevent blowing out the polymer. Very reliable operations and very little downtime are possible Does not work with high inorganic dust concentrations</p>	
<p><b>Other adsorption techniques</b> (Not included in calculations of removal efficiency)</p>		
<p><b>Oil scrubbing</b> VOC removal efficiency generally relatively low. Mainly used for abating emissions of inorganics or odours</p>		
<p><b>Coolsorption <i>ESVOC</i></b> <i>propose deletion</i> <del>Scrubbing with a refrigerated absorbent.</del> Combines absorption with condensation</p>		
<p><b>Water scrubbing</b> Several types exist. Waste gases are led through a curtain of water or water mist. Particularly suited for the removal of droplets and dust. Waste water treatment is necessary</p>		Water soluble VOCs
<p><b>Condensation</b></p>		
<p><b>Condensation at ambient temperature, no inert gas dryer <i>ESVOC</i></b> <i>propose deletion</i> (Not included in calculations of removal efficiency) <del>Waste gases are cooled down to a temperature above freezing point. Low volatility solvents condense. High volatility solvents, however, are not condensed effectively</del></p>	<p><del>The equipment is very simple and not expensive.</del> <del>No information about operating costs</del></p>	<p>No examples of successful application in industries in the scope of this document are known</p>
<p><b>Condensation with inert gas dryer</b> <i>ESVOC</i> <i>propose deletion</i> In an enclosed drying system containing an inert gas (mostly nitrogen) the solvent concentration is allowed to rise to several hundred grams per m<sup>3</sup>. The inert gas is led through a condenser where a part of the solvents are condensed at approximately room</p>	<p>The driers are obviously more expensive than traditional driers. The operational costs depend to a large extent on the amount of nitrogen used. Nitrogen is used mainly when the drier needs to be opened, for instance in the case of job changes. Where mixtures of solvent are used, complex techniques may be necessary to make the recovered solvents ready for re-use. Since the drier needs to be as closed as possible, the technique can only be used for drying thin even substrates that can be</p>	<p>The technique is only applicable where there is no need to open the drier for several days in a row</p>

End-of-pipe technique and description	Conditions for applicability	Applicable:
temperature. The inert gas with a reduced solvent content is returned to the drier. The condenser is often cooled with the liquid nitrogen that is also needed for topping up the drier system	led through the drier without serious leaks at the entry and exit	
<b>Other condensation techniques</b> (Not included in calculations of removal efficiency)		
<b>Refrigerated condensation:</b> <i>ESVOC propose deletion</i> The waste gas is cooled to a temperature below 0 °C. Icing occurs and regular de-icing is necessary. For that purpose there are usually two condensers. A condensation step above 0 °C upstream reduces the water content of the waste gas.	The running costs are high and increase if a lower condensation temperature is necessary	Mostly for the recycling of higher cost solvents. Low airflows with high concentrations
<b>Cryogenic condensation:</b> Condensation at very low temperature usually with liquid nitrogen		Mostly for the recycling of higher cost solvents. Low airflows with high concentrations
<b>Biological</b> <b>Biological treatment</b> (Not included in calculations of removal efficiency) The waste gas is blown through a bed of organic material in which the VOCs are adsorbed and destroyed (metabolised) by bacteria	The equipment is simple and not expensive, but needs a lot of space in the case of large airflow. Bacteria are easily killed by changing the composition of the waste gas or by lack of feed in the holiday season. This affects the filter efficiency. No information about operating cost	Waste gas stream with low concentration. Biodegradable and preferably water soluble components. Odour problems

**Removal efficiencies**

Table 21.15 and Table 21.16 below give the removal efficiency of oxidation techniques and solvent recovery with activated carbon. For other techniques, insufficient data were available to produce similar tables.

Removal efficiency depends on:

- the carbon content of the solvent molecule
- the average inlet concentration
- the average outlet concentration
- operating temperature (see technical note below).

The shaded bands in the tables give the range of removal efficiency that can be expected from either oxidation or solvent recovery.

The lower parts of the band correspond to the lower inlet concentrations.

The attainable solvent concentrations in the waste gases for solvent recovery are somewhat higher than in the case of oxidation. The removal efficiencies are therefore somewhat lower.

**The effectiveness of the oxidation**

The effectiveness of the oxidation of VOC is dependent on three parameters:

- a) Turbulence: A complete movement and mixture of the waste gases in the burner chamber.
- b) Time: Minimum residence time of the waste gases in the burner chamber (typically 1 second).
- c) Temperature: The burner chamber operating temperature (typically in the range of 720 to 850 °C).

Points (a) and (b) are design parameters set by the manufacturer. Point (c) (temperature of the burner) is the only parameter available for adjustment by the operator. It must be noted, however, that high energy demands and increased NO<sub>x</sub> levels will result from elevated running temperatures when attempting to increase VOC removal efficiency.

**Inorganic dust**

The techniques are sensitive to inorganic dust to varying degrees. Some are very sensitive, others less so, or they can be adapted. Inorganic dust is likely to affect the efficiency of the technique and/or gas throughput (higher airflow resistance) and the amount of maintenance required. Adapting to waste gases with inorganic dusts can therefore have an impact on capital and running costs.

**Calculations**

The removal efficiency equals 100 % minus the percentage of remaining carbon after the abatement equipment. The percentage of carbon remaining is calculated by dividing the 24 hour average outlet concentration by the 24 hour average inlet concentration. For this calculation, the inlet concentration is expressed in g/m<sup>3</sup> solvent, multiplied with the percentage carbon content of the solvent. The outlet concentration is expressed in mg carbon per m<sup>3</sup>.

The 24 hour average outlet concentrations are based on experience in installations that today are subject to EoP emission limit values. It must be noted that, in order to be certain of compliance, the actual 24 hour average outlet concentrations are always lower than these EoP emission limit values.

It must also be noted that the actual EoP concentration may vary widely over the day, depending on the production circumstances in the installation.

**Carbon content**

The carbon content of a solvent can be determined on the basis of a chemical formula. For reasons of simplicity, four categories are given in Table 21.15 for use in Table 21.16 and Table 21.17.

**Table 21.15: Chemical groups of common solvents and their carbon content**

Solvent group	Average carbon content (%)	Chemical groups of solvents
Group 1	55.0 %	Alcohols, glycol ethers, glycol, ether esters
Group 2	65.0 %	Esters, ethers, ketones
Group 3	85 %	Hydrocarbons
Group 4. Exceptionally low carbon content compared to other chemicals in their group	37.5 %	Methanol
	48.6 %	Methyl acetate

**Removal efficiency and BAT**

Table 21.16 and Table 21.17 provide information about the range of removal efficiencies associated with oxidation and solvent recovery (activated carbon adsorption). These tables do NOT imply that compliance with every single value in the ranges can be considered BAT.

The emission ranges attainable by the application of BAT are given in the industry-specific parts of Chapter 21 in this document. These emission ranges associated with BAT always apply to the total of both end-of-pipe emissions and fugitive emissions.

Where the emission range associated with BAT is, for instance, 10 % of solvent consumption, and the fugitive emissions account for 5 % of solvent consumption, the removal efficiency of the abatement equipment must be over 95 %.

The abatement equipment must obviously be chosen in such a way that it will reduce emissions sufficiently to attain the emission range associated with BAT and still leave room for unavoidable fugitive emissions.

**Removal efficiency and end-of-pipe emission limit values**

The Solvent Emissions Directive and similar national legislation may prescribe end-of-pipe (EoP) emission limit values. These values may be different for different industries. Attainment of the lower parts of the removal efficiencies ranges given in Table 21.16 and Table 21.17 may not lead to compliance with these emission limit values (ELVs). Indeed compliance with some especially low emission limit values may require removal efficiencies higher than the highest value given in the tables. This may, for instance, be the case where solvents are used such as mentioned in Art 5.6 of the Solvent Emissions Directive (carcinogens, mutagens or toxic to reproduction).

Table 21.16: Removal efficiency of oxidation techniques

Oxidation	Removal efficiency	75.0 %	80.0 %	85.0 %	90.0 %	92.5 %	95.0 %	97.5 %	99.0 %	99.5 %	99.9 %
<b>Group 1 solvents</b>	0.5 - 1.0 g solvent/m <sup>3</sup>										
Inlet concentration	1.0 - 2.0										
	2.0 - 6.0										
	6.0 - 12.0										
<b>Group 2 solvents</b>	0.5 - 1.0 g solvent/m <sup>3</sup>										
Inlet concentration	1.0 - 2.0										
	2.0 - 6.0										
	6.0 - 12.0										
<b>Group 3 solvents</b>	0.5 - 1.0 g solvent/m <sup>3</sup>										
Inlet concentration	1.0 - 2.0										
	2.0 - 6.0										
	6.0 - 12.0										
<b>Methanol</b>	0.5 - 1.0 g solvent/m <sup>3</sup>										
Inlet concentration	1.0 - 2.0										
	2.0 - 6.0										
	6.0 - 12.0										
<b>Methyl acetate</b>	0.5 - 1.0 g solvent/m <sup>3</sup>										
Inlet concentration	1.0 - 2.0										
	2.0 - 6.0										
	6.0 - 12.0										

Table 21.17: Removal efficiency solvent recovery for activated carbon

Activated carbon recovery	Removal efficiency	75.0 %	80.0 %	85.0 %	90.0 %	92.5 %	95.0 %	97.5 %	99.0 %	99.5 %	99.9 %
<b>Group 1 solvents</b>	0.5 - 1.0 solvent/m <sup>3</sup> <sub>ofg</sub>										
Inlet concentration	1.0 - 2.0										
	2.0 - 6.0										
	6.0 - 12.0										
<b>Group 2 solvents</b>	0.5 - 1.0 solvent/m <sup>3</sup> <sub>ofg</sub>										
Inlet concentration	1.0 - 2.0										
	2.0 - 6.0										
	6.0 - 12.0										
<b>Group 3 solvents</b>	0.5 - 1.0 solvent/m <sup>3</sup> <sub>ofg</sub>										
Inlet concentration	1.0 - 2.0										
	2.0 - 6.0										
	6.0 - 12.0										
<b>Methanol</b>	0.5 - 1.0 solvent/m <sup>3</sup> <sub>ofg</sub>										
Inlet concentration	1.0 - 2.0										
	2.0 - 6.0										
	6.0 - 12.0										
<b>Methyl acetate</b>	0.5 - 1.0 solvent/m <sup>3</sup> <sub>ofg</sub>										
Inlet concentration	1.0 - 2.0										
	2.0 - 6.0										
	6.0 - 12.0										



## 21.10 Additional information on printing

[4, Intergraf and EGF, 1999] [78, TWG, 2005] unless stated differently.

[This is information from the original BREF not fitted into the 3 new Chapters for the printing sectors. To be clarified on a later stage if this information will be remain as additional information ]

### 21.10.1 Printing industry in the European Union Community

The printing industry is one of the largest of the European Union's manufacturing industries, being in the top ten of such industries in most countries. It is an industry which serves all sectors of the economy including public authorities, financial services, publishers, distributive services and manufacturing industries. Its customers range from major institutions to the smallest business. There are many thousands of competing firms, with capacity exceeding market take-up in most areas, so competition is intense. The entire industry in EU-25 and EFTA countries employs about 970000 people in about 125000 companies with a combined turnover of about EUR 170000 million, see Table 21.18 and

Table 21.19, The notes to Table 21.20 describe the printing activities included in these figures, which include many activities and installations outside the scope of this document.

**Table 21.18: Number of printing enterprises in European countries**

		2000	2001	2002	2003	2004
<b>EU-25<sup>(a)</sup></b>						
BE	Belgium		1794	1693	1683	1633
CZ	Czech Republic	4112	3708 <sup>(b)</sup>	5286	6100	-
DK	Denmark	1736	1569	1473	1352	-
DE	Germany	13584	14680	12934	12574	-
EE	Estonia	140	153	168	168	-
EL	Greece	-	-	-	-	-
ES	Spain	15445	14452	14445	13958	-
FR	France	17114	16962	16766	-	-
IE	Ireland	353	357	380	-	-
IT	Italy	20400	20320	20269	19603	-
CY	Cyprus	277	302	316	318	-
LV	Latvia	273	258	-	-	-
LT	Lithuania	262	274	291	295	-
LU	Luxembourg	86	78	77	-	-
HU	Hungary	661	4265	4322	-	-
MT	Malta	194	189	-	-	-
NL	Netherlands	2976	2848	2668	3665	3183
AT	Austria	1045	1010	1088	1095	-
PL	Poland	11001	10333	11416	-	-
PT	Portugal	3055	3116	2988	3237	-
SI	Slovenia	1282	1413	1133	-	-
SK	Slovakia	186	240	245	201	-
FI	Finland	1368	1311	1276	-	-
SE	Sweden	3951	3835	3683	-	-
UK	United Kingdom	18937	18814	18777	18283	-
<b>Totals:</b>		<b>118438</b>	<b>118573</b>	<b>121694</b>	-	-
<b>EFTA<sup>(a)</sup></b>						
NO	Norway	1100	-	-	-	-
CH	Switzerland	2634	-	-	-	-
(a)	Economical indicator for structural business statistics. Classification of economic activities – NACE Rev.1.1 – DE 22.2					
(b)	Provisional value					
Extract from Eurostat New Chronos database. Company size coverage may vary from country to country						
Source: [125, Eurostat, 2005/6]						

Table 21.19: Number of employers in the European printing industry

		2000	2001	2002	2003	2004
<b>EU-25<sup>(a)</sup></b>						
BE	Belgium		22006	21309	19586	19169
CZ	Czech Republic	-	17531 <sup>(b)</sup>	18118	20274	-
DK	Denmark	16643	15023	14025	12590	-
DE	Germany	196489	191822	186432	165511	-
EE	Estonia	<sup>(c)</sup>	<sup>(c)</sup>	2489	2336	-
EL	Greece	-	-	-	-	-
ES	Spain	87209	82852	84949	82864	-
FR	France	120978	119698	115796	-	-
IE	Ireland	8672	8523	7936	-	-
IT	Italy	99106	98980	93680	94903	-
CY	Cyprus	1382	-	-	1573	-
LV	Latvia	3609	3917	-	-	-
LT	Lithuania	3145	3363	3515	3628	-
LU	Luxembourg	1141	1143	1140	-	-
HU	Hungary	16076	21213	23683	-	-
MT	Malta	1284	1249	-	-	-
NL	Netherlands	48447	48006	46550	36532	47900
AT	Austria	16803	16560	16066	15196	-
PL	Poland	38653	38233	34684	-	-
PT	Portugal	24588	25259	22857	24762	-
SI	Slovenia	5731	5778	6058	-	-
SK	Slovakia	5592	6118	5046	3863	-
FI	Finland	13317	13129	12390	-	-
SE	Sweden	24314	23839	22606	-	-
UK	United Kingdom	-	201000	191000	185000	-
<b>Totals:</b>		<b>733179</b>	<b>947711</b>	<b>930329</b>	-	-
<b>EFTA<sup>(a)</sup></b>						
NO	Norway	10476	-	-	-	-
CH	Switzerland	32302	-	-	-	-
(a) Economical indicator for structural business statistics. Classification of economic activities – NACE Rev.1.1 – DE 22.2						
(b) Provisional value						
Extract from Eurostat New Chronos database. Company size coverage may vary from country to country						
<b>Source: [125, Eurostat, 2005/6]</b>						

As well as printing on paper, additional markets for printing on other substrates such as plastics, cardboard and metal are also considerable (for printing on metal, see Metal packaging, Chapter 10).

While many of the listed products can be produced on the same kind of machine, economics dictate that some of them have to be printed on specialised equipment. The main processes described all have specific properties and associated costs, and are used as requirements demand. Sometimes, more than one process may be used on the same job, and occasionally a specific printing press may incorporate more than one process.

Printing processes convert original text and Pictures into an image on a carrier (but see digital, below), and the main process types are named according to how this image is carried. The carrier can be a plate, cylinder or stencil. All image carriers have two separate surfaces – an image (printing) area and a non-image (non-printing) area. The image area accepts the ink, but the non-image area does not accept or retain any ink.

Table 21.20: Turnover of the European printing industry, all activities

	Turnover (Total, million EUR)				
		2001	2002	2003	2004
<b>EU-25</b>					
BE	Belgium	7698	7548	7244	7319
CZ	Czech Republic				
DK	Denmark	3418.3	3248.7	2904.4	
DE	Germany	34404	32692	32828	33050
EE	Estonia	45.2	141.5	182.9	
EL	Greece				
ES	Spain	5855	6070	6090	6325
FR	France	22454.5	12003.2	21046.9	
IE	Ireland	829	800.7		
IT	Italy	21593.5	22531.7	22447.3	
CY	Cyprus	177.7	165.1	158	
LV	Latvia		184.3	193	
LT	Lithuania	150	183.2	182.8	
LU	Luxembourg	279.425	281.643	309.557	
HU	Hungary	1441.4	1679.1		
MT	Malta	139.7	169.1		
NL	Netherlands	11516.1	10954.8	10134.9	
AT	Austria	3317.5	3264.6	3274.7	3287.47
PL	Poland				
PT	Portugal	253.3	153.8	89.2	
SI	Slovenia				
SK	Slovakia	374.4	370.9	368.2	
FI	Finland	3326	3198	3055	3147
SE	Sweden	9048	8914	8684	8850
UK	United Kingdom	44225.4	42146.2	35043.9	
	<b>Total EU-25:</b>	186327.1	172291.8	166318.2	
<b>EFTA</b>					
NO	Norway	2784.4	2837.3		
CH	Switzerland	13000	12800	12400	12500
NB: The totals are the sum of all economic activities in NACE Rev.1.1 - DE 22.2, Printing and service activities related to printing: <ul style="list-style-type: none"> <li>◦ 22.21: Printing of newspapers</li> <li>◦ 22.22: Printing</li> <li>◦ 22.23: Book binding</li> <li>◦ 22.24: Pre-press activities (composition and plate-making)</li> <li>◦ 22.25: Ancillary activities related to printing</li> </ul> Source: [125, Eurostat, 2005/6]					

The main printing processes are listed below and described in Section 21.10.3:

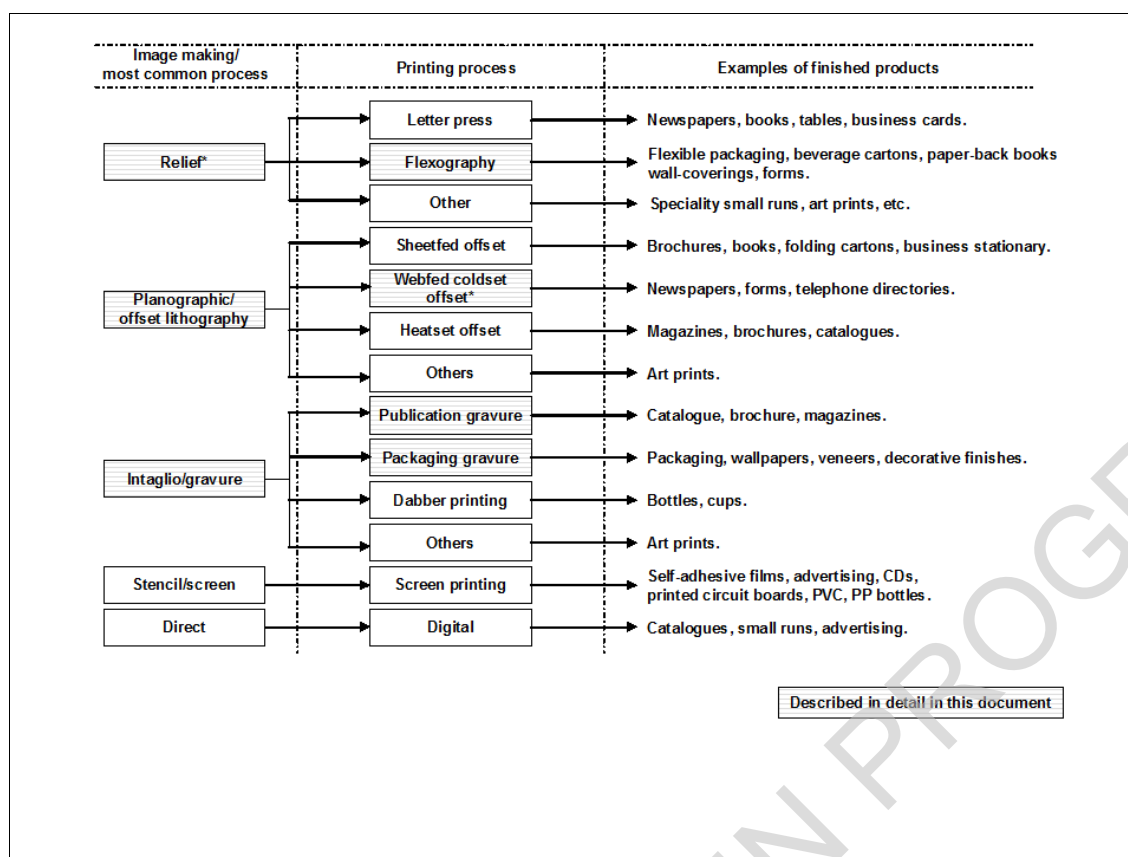


Figure 21.6: Overview of main printing processes

### Relief printing

This uses a printing surface that is in relief, i.e. raised above the non-printing surface. *Letterpress* and *flexography* are examples of this process. Flexographic printing can run in installations large enough to exceed the criteria in IPPCD Annex 1 (6.7), but often at this size it is found running with packaging gravure, together with laminating and varnishing.

### Offset printing

The image and non-image areas are in the same plane on a plate, which can be of metal, plastic or paper (a technique known as *lithography*, usually abbreviated to '*litho*').

Because offset plates do not last when being constantly abraded by contact with the printing substrate on long print runs, the image is put or 'offset' onto a softer intermediate blanket which transfers the image to the substrate. This type of printing is known as '*offset*' and is the most commonly used process.

The substrate can be fed as a roll or web, known as '*webfed*', or as sheets ('*sheetfed*'). '*Heatset*' and '*coldset*' refers to the technique used to dry the ink. Heatset web offset can run in installations large enough to exceed the criteria in IPPCD Annex 1 (6.7).

### Gravure

This is the best known of the intaglio printing processes, but copperplate and die stamping are others. Here, the printing areas are tiny recesses inscribed on a cylinder below the non-printing areas. These recesses are filled with ink, the surplus ink is removed and the substrate is pressed against the printing cylinder. Publication gravure and packaging gravure can run in installations large enough to exceed the criteria in IPPCD Annex 1 (6.7).

### Stencil

**Screen printing** is an example of stencil printing, in which the printing and non-printing areas are carried on a screen. The non-printing areas are formed by blocking out parts of the screen, while the ink is forced through the non-blocked parts onto the substrate.

### **Digital**

Produces an image directly onto a substrate from digital information without the creation of an intermediate permanent image.

### **The business use of the processes**

While many businesses also handle the creation of the image and all the processes involved before the actual printing takes place, along with the binding and finishing, a large number of companies exist solely to do these specific operations. Equally, many thousands of commercial firms such as banks do their own printing in-house.

Additionally, there are many high street printing shops (copy shops). Traditionally, they used the same equipment as the smaller 'conventional' printer, but now these businesses are based on photocopying and inkjet and/or digital printing.

## **21.10.2 The products**

### **21.10.2.1 Newspapers**

Virtually all newspapers are printed by coldset web offset. A typical local newspaper plant could have one or two presses with four units on each press, but larger, specialist printers doing national newspapers may have as many as ten presses. Coldset machines with a narrower web are also used for the production of advertising flyers, paperback books and telephone directories.

Older letterpress machines may still be found in some countries, but their use has declined rapidly over the last 20 years. One or two firms have changed to the flexography process recently. Where the newspaper printers switch to flexography, this is always water-based.

### **21.10.2.2 Magazines and catalogues**

Magazines with a circulation of over 10000 are generally printed by heatset web offset, although shorter runs will be done by sheetfed offset. Heatset web offset is also used to print travel brochures, mail order catalogues, and advertising material for inserting into newspapers and magazines. It is also used for printing some colour books.

Very long run magazines and similar publications tend to be printed by gravure, where the extra costs of making a gravure cylinder over those of offset plate making, can be sustained. As a result of the high level of investment and the high output, these processes are generally used in large companies.

Gravure has a reputation for being able to print on relatively poor paper surfaces, yet still achieve a good, rich print. Heatset web offset, on the other hand, requires a good coated or uncoated paper to achieve the same quality. Some firms have both gravure and heatset web offset presses to print magazines of different run lengths.

### **21.10.2.3 Books**

Most colour and short-run black and white books tend to be printed by sheetfed offset, whereas long-run single colour books such as paperbacks are printed on the web, usually by coldset web

offset but sometimes by letterpress. Mainly, sections of 8, 16 or 32 pages are printed at one time, and then bound to produce the book.

Several hundred firms in each country are capable of printing short-run books by sheetfed offset, for in-house or off-site binding. Long-run work would only be done by a few specialists.

A very small number of specialised continuous belt presses are in existence, which print the entire book in one operation, rather than in several separate sections. These normally print by letterpress using flexible plates. The production of short-run books and booklets is mainly a local operation, but long-run work is open to national and international competition.

#### **21.10.2.4 General printing**

There is an enormous variety of printed work known as general or commercial work, which includes advertising literature, company reports and accounts, greetings cards, calendars, brochures, leaflets, posters and the like, which are printed by sheetfed offset.

#### **21.10.2.5 Security printing**

The general category of security printing includes a large number of products, from banknotes, passports, stamps, cheques, tickets and coupons to those that rely on the security of the information, such as company reports and accounts, city financial documents and examination papers. This requires a wide range of processes, some of which are specific only to security printing.

#### **21.10.2.6 Labels**

There are basically two types of label, i.e. wet labels and self-adhesive roll labels. The former are usually printed by conventional sheetfed offset, then guillotined for subsequent glueing and wrapping around cans and bottles. Self-adhesive labels are printed on a web made up of several layers, including the backing paper, adhesive and front layer, which is printed and cut to the desired shape.

Self-adhesive roll label printing is a highly specialised operation and the equipment is only used for that purpose. The presses may be rotary letterpress, flexo, or offset (water-based or waterless), and may also incorporate screen printing and foil blocking. A specific press may incorporate several processes.

#### **21.10.2.7 Business forms**

The printing of business forms is also highly specialised, although the market is rapidly declining due to ever increasing IT capabilities. It can be broken down into two areas: continuous forms and cut sets which are usually A4 size. Business form sets may be printed in sheet form, then collated to form the set, and glued by pasting one edge of a thick block of many sets, for later separation by the user.

#### **21.10.2.8 Paper and cardboard packaging**

Paper and cardboard packaging comes in three main forms: paper packaging such as paper bags, and cartons made from either solid or corrugated cardboard. It is a very large market, of around the same order of magnitude as the markets for newspapers, books and security printing.

Cheap paper bags will often be printed by flexography, using water-based inks.

There are a number of markets: food and drink packaging, and pharmaceuticals are the largest. With food packaging, printing is often done using UV inks, to ensure complete drying (curing) and no leaching of ink into the food.

Cartons made of solid board are printed by sheetfed offset on large, multicolour machines, to a high quality and accuracy. Corrugated board is generally printed in water-based sheetfed flexography [38, TWG, 2004].

For longer runs, printing may be by web offset, flexography or gravure. Gravure is used when high quality is required, for instance, for cigarette packets.

#### **21.10.2.9 Products requiring thick ink films**

Screen printing produces a characteristically thicker film and is therefore used for many different products such as:

- high visual impact such as in the point of sale advertising, posters, car decals
- PVC, polycarbonate or PET bottles
- CDs, DVDs
- printing designs onto paper for transfer to T-shirts using heat
- some specialist wall coverings
- the thick coatings needed for 'scratch card' gaming tickets
- the magnetic strips on railway tickets and credit cards
- applying etch resist in making printed circuit boards (more information can be found in the STM BREF [59, EIPPCB, 2006])
- textiles.

The substrates printed in screen printing consist of about 40 % of the printing on self-adhesive films, 20 % of printing on plastics (including rigid plastics), and 20 % of printing on cardboard. Much use of the process is also made in printing on textiles and metals. Run lengths are usually very small, with two thirds of all orders being under 1000 copies.

#### **21.10.2.10 Wallpaper, decorative paper and paper-based foils for the furniture and lamination industry**

A variety of processes are used to print wall coverings, with gravure (similar to packaging gravure) and flexography having largely replaced offset. Many products are also embossed, and it is quite common to see combinations of all three processes used on the same reel of wall covering.

Many printers use the same range of inks to print both vinyl-coated and plain papers by both gravure and flexography. One or two firms have recently started to introduce water-based gravure inks, but these are still very much in the minority as the process needs more development for most products.

Some specialist firms use the screen process for short-run, expensive wall coverings.

#### **21.10.2.11 Envelopes**

Envelopes can be printed by flexography for the inside, and using water- or solvent-based inks for the outside. Printing, gluing and die cutting can be carried out at the same time from a reel. Alternatively, envelopes can be 'pre-printed' by offset, and printed sheets or printed reels are

die cut after printing. Supplementary to this, the finished envelope can be printed on the outside by sheetfed offset using conventional or UV drying inks [38, TWG, 2004].

### **21.10.3 Applied processes and techniques in printing**

Production processes in graphic production are schematically shown in. The printing process can be divided into four main unit processes: pre-press and proofing systems, making the image carrier printing, and finishing, and they are discussed in the following sections. Of these four processes, the printing process has the most significant environmental impacts: the others are associated activities and are explained in general terms to give a clear idea of printing installations [38, TWG, 2004, 78, TWG, 2005].

#### **21.10.3.1 Pre-press and proofing systems**

The pre-press processes include text and image processing. It is fairly similar for all printing technologies. Today it is mainly produced electronically. Once the desired format and images are assembled, the data can be transferred in one of two ways:

- exposed on photographic film. The photographic emulsion on the film is composed of silver halide and gelatine. The exposed film is developed, fixed and rinsed in automatic machines. This method is used decreasingly, and largely when the film is the end-product of the pre-press stage
- digitally. This is becoming the predominant method [38, TWG, 2004].

A proof print is often made for checking the reproduction process. Today, proofs can be made directly from the data in the computer being shown on the screen, or being printed out with an inkjet or laser print [8, Nordic Council of Ministers, 1998].

Organic solvents are not used in the pre-press process and there are normally no other emissions to air. Emissions to water from the pre-press process can be silver compounds in the rinsing water, used developer, or fixer and chromium compounds from cleaning chemicals [8, Nordic Council of Ministers, 1998].

#### **21.10.3.2 Creating the image carrier: printing plate, cylinder, stencil making and computer-to-plate (CTP)**

The image carriers are used in the printing processes to transfer the printing ink directly or indirectly (offset processes transfer the ink indirectly) to the substrate (paper, cardboard, plastic, etc.). They are normally made by copying the films onto light-sensitive coatings on the printing plates, cylinders or screens, respectively. Before this, the films have to be mounted so that they correspond to the size of the printing form and the printing sheet or web. The printing form has to be developed or washed-out, and sometimes engraved or etched, before it is ready for printing.

New technology makes it possible to produce printing forms directly from the computer without the photomechanical process and the photographic films are no longer needed. The process is known as computer-to-plate (CTP) [8, Nordic Council of Ministers, 1998].

Degreasing, etching and electroplating are techniques used in cylinders in the gravure process and are discussed in the STM BREF [59, EIIPCB, 2006]. The STM BREF also discusses the application and forming of photopolymers, which are used in printing designs during the production of printed circuit boards.

#### ***Letterpress and flexography***



The printing plates used in letterpress printing are made of photopolymers which cross-link and harden under exposure to UV light [38, TWG, 2004]. While some plates still have to be processed using solvents, most systems rely on water-based methods and jets of air [4, Intergraf and EGF, 1999].

Origination and image-forming for the flexographic process are the same as for a letterpress, except that the photopolymers used are softer. They can also be made of rubber.

### ***Litho, offset***

The printing plates are usually aluminium coated with a photosensitive coating, although the base can be plastic or special papers. The image is formed photochemically, leaving a surface area of the plate treated to receive ink in the relevant (image) areas. The non-printing areas are 'wetted' by a water or water-solvent mixture called the dampening solution, which rejects ink. The waterless offset process uses special plates which have an ink-repelling surface which is photochemically removed in the printing areas.

### ***Gravure***

The cylinder used in the gravure printing process consists of a steel base which is plated with copper (more information can be found in the STM BREF [59, EIPPCB, 2006]). The image is then engraved in the copper, usually by using electromechanical or laser-engraving machines. A minority of cylinders are still made by traditional photographic and etching methods. The cylinder is degreased, deoxidised and polished. Following this, a thin layer of hard chromium is electroplated on to protect the image in the softer copper. Chromium is deposited by electrolysis in a bath containing chromic oxide and sulphuric acid (see the STM BREF [59, EIPPCB, 2006]). Again, after the chrome plating, the cylinder is polished [38, TWG, 2004].

The production of the cylinder is slow and expensive, compared to other printing methods, and the cylinder is heavy and difficult to handle. It is therefore used in gravure printing only for long runs, as heatset can achieve similar quality. ~~In packaging gravure, the alternative (flexography) does not achieve such a high quality, and the runs can often repeat using the same cylinders.~~ [78, TWG, 2005]

### ***Screen printing***

The image carrier is a stencil supported by a fabric stretched tightly on a frame. This image carrier is called a screen.

The production of screen stencils falls into four main categories: hand cut stencils, electronically cut stencils, photomechanical stencils and the direct method.

In the first of these, the stencil is cut by hand with a sharp scalpel from adhesive-backed masking material. The second method is a development of this, when the stencil is cut using computer controlled techniques. The manually or computer generated artwork is scanned with the controlling drafting head directing a cutting blade or stylus to create complex, accurate stencils from masking material. While use of this latter method will undoubtedly increase with computer automation, the major method in use today is the photomechanical stencil.

With photomechanical stencil making, light-sensitive material is exposed to an opaque positive image, thus hardening the non-image areas hit by light and rendering them insoluble. The unexposed image areas are dissolved away to leave open, clear reverse stencil areas.

With the direct method, the screen is coated with a photosensitive emulsion, and the image is projected directly onto the photostencil from a UV light source. After exposure the image is washed out in the same manner as other methods. This avoids the generation of an opaque positive image [38, TWG, 2004].

### 21.10.3.3 Printing

After the image carrier has been mounted in the press, the printing can be started.

### 21.10.3.4 Letterpress and letterset

[4, Intergraf and EGF, 1999] [8, Nordic Council of Ministers, 1998]

Letterpress and letterset are (as flexography) relief printing methods, where the image is raised compared with the then non-printing areas. Letterpress was the most widely used printing process up until the early 1970s when offset lithography and other processes superseded it for a variety of reasons including higher speeds, better quality and lower unit costs. Nowadays, wooden blocks and metal type have been replaced by a plastic relief plate, which is obtained by exposure of a negative film to light, the light hardening the plate in the image areas and the unhardened areas being processed away. Flatbed letterpress has limited uses for a range of short-run general jobbing work.

Letterset is an indirect flexographic printing process. The image is transferred to a rubber blanket (as in offset) and then onto the object to be printed. This is used for printing beverage cans, often with solvent-based inks (see Chapter 10) [38, TWG, 2004].

Cleaning operations are mainly done by hand with the same cleaning materials as used in the offset processes.

## GLOSSARY

### General terms, abbreviations, acronyms and substances

ENGLISH TERM	MEANING
Alphanumerics	
2K	two-component, usually used for paints
A	
AC (e.g. paint)	No data submitted.
acid	a proton donor: a substance that liberates hydrogen ions in water solution
aerobic	a biological process that occurs in the presence of oxygen
alkali (base)	a proton acceptor. A substance that liberates hydroxide ions in water solution
anaerobic	a biological process which occurs in the absence of oxygen
AOX	adsorbable organic halogen compounds. The total concentration in milligrams per litre, expressed as chlorine, of all organic halogen compounds (except fluorine) present in a sample of water that are capable of being adsorbed on activated carbon
B	
BAT	best available techniques
biodegradable	that can be broken down physically and/or chemically by micro-organisms. For example, many chemicals, food scraps, cotton, wool and paper are biodegradable
BIW, body in white	a standard term in the vehicle manufacturing industry and refers to the bare metal shell of the vehicle before it has been degreased, dipped and painted
BOD	biochemical (or biological) oxygen demand: a measure of the content of organic matter in water and wastes. It is the amount of dissolved oxygen required by micro-organisms in order to decompose organic matter. The unit of measurement is mg O <sub>2</sub> /l. In Europe, BOD is usually measured after 3 (BOD <sub>3</sub> ), 5 (BOD <sub>5</sub> ) or 7 (BOD <sub>7</sub> ) days
b.p.	boiling point
BREF	BAT reference document
C	
CAD	computer aided design
CAFE	Clean Air For Europe: the programme that underpins the EU's thematic strategy on air pollution
CBN	cubic boron nitride
CEN	European Committee for Standardization
CMR	carcinogenic, mutagenic and reprotoxic: applied to substances that have all or some of these hazardous properties
COD	chemical oxygen demand: the quantity of oxygen absorbed chemically (by a sample). The test conditions are strongly oxidising using potassium dichromate and oxidises virtually all organic compounds. The unit of measurement is mg O <sub>2</sub> /l
containment, contained area	(secondary) containment refers to additional protection against storage tank releases over and above the inherent protection provided by the tank container itself. There are two major types of secondary containment for leakages, namely those that are part of the tank construction, such as double tank bottoms (only for aboveground tanks), double skinned and double walled tanks and impervious barriers which are placed upon the soil surface below the tanks [44, COM, 2005]
cross-media effects	the calculation of the environmental impacts of water/air/soil emissions, energy use, consumption of raw materials, noise and water extraction (i.e. everything required by the IPPC Directive)
CSBR	carboxylated styrene butadiene styrene block copolymer
CTP	computer-to-plate
D	
DEHP	Bis(2-ethylhexyl) phthalate
dH	water hardness degree
DIN	Deutsche Industry Norm

## Glossary

ENGLISH TERM	MEANING
DS	dry solids (content): the mass of a material remaining after drying by the standard method of test
DWI	draw and wall iron: a production method for producing cans
E	
EB	electron beam
EDTA	ethylene diamine tetra acetic acid
EF	emission factors
effluent	physical fluid (air or water together with contaminants) forming an emission
EFTA	European Free Trade Association
EGTEI	See Annex 21.3.1 EGTEI home page: <a href="http://www.citepa.org/forums/egtei/egtei_index.htm">http://www.citepa.org/forums/egtei/egtei_index.htm</a>
EIPPCB	European IPPC Bureau
ELV	emission limit values: the mass, expressed in terms of certain specific parameters, concentration and/or level of an emission, which may not be exceeded during one or more periods of time
EMAS	environmental management and audit scheme
emission	the direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources in the installation into the air, water or land
EMS	environmental management system
'end-of-pipe' technique	a technique that reduces final emissions or consumption by some additional process but does not change the fundamental operation of the core process. Synonyms: 'secondary technique', 'abatement technique'. Antonyms: 'process-integrated technique', 'primary technique' (a technique that in some way changes the way in which the core process operates, thereby reducing raw emissions or consumption)
environmental footprint	a measure of the burden or impact that a product, operation or business places on the environment. For IPPC, this will be: <ul style="list-style-type: none"> <li>• the consumption of energy, raw materials and water</li> <li>• emissions to air, water, groundwater, and soil; and as waste</li> <li>• damage to material property and the impairment or interference with amenities and other legitimate uses of the environment.</li> </ul> IPPC includes a consideration of noise and vibration, dust and odour. However, it does not include aspects such as life cycle analysis of products
EOE	easy-open ends
EP	electrostatic precipitator
EPDM	ethylene-propylene-diene monomer
EQS	environmental quality standard
ESIG	European Solvents Industry Group
ETL	electrocoating, e.g. electrophoretic dipping and cathodic immersion
EU	European Union
EUA	European Union Allowance: the term used for the trading units for the EU carbon trading scheme in EUR per tonne CO <sub>2</sub>
EVA	ethylene vinyl acetate
EWP	Environmental Working Party
existing installation	an installation in operation or, in accordance with legislation existing before the date on which this Directive is brought into effect, an installation authorised or in the view of the competent authority the subject of a full request for authorisation, provided that that installation is put into operation no later than one year after the date on which this Directive is brought into effect
F	
FID	flame ionisation detection
flat tint	a printed area containing halftone dots that are all the same size, as opposed to a halftone or a vignette. Flat tints are usually just called 'tints'
flocculation	waste water treatment involving gentle stirring whereby small particles in flocs are collected into larger particles so their weight causes them to settle to the bottom of the treatment tank
FOGRA	

ENGLISH TERM	MEANING
footprint	a company's environmental impact determined by the amount of depletable raw materials and non-renewable resources it consumes to make its products, and the quantity of wastes and emissions that are generated in the process
fugitive emission	in this document, the IED definition is used: any emissions not in waste gases of volatile organic compounds into air, soil and water as well as solvents contained in any products, unless otherwise stated in Part 2 of Annex VII; They include uncaptured emissions released to the outside environment via windows, doors, vents and similar openings (conversely, see also waste gas)
G	
GDP	gross domestic product
GJ	gigajoule
GRT	gross registered tonnes
GT	gross tonnes
H	
HBS	high-boiling solvents
HDF	high density fibre
HF	high frequency
HP	high pressure
HVLP	high-volume low-pressure
I	
IBC	intermediate bulk container
IDOP	integrated downwind ozone production: a measure of the reactivity of a solvent in creating tropospheric ozone
IEC	International Electrotechnical Commission
IEF	Information Exchange Forum (informal consultation body in the framework of the IPPC Directive)
immission	occurrence and level of polluting substance, odour or noise in the environment
IMO	International Maritime Organisation
installation	a stationary technical unit where one or more activities listed in Annex I are carried out, and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution
Intergraf EWP	environment working party
IPA	iso propyl alcohol
IPPC	integrated pollution prevention and control
IR	infrared
J	
K	
K1 K2 K3	an indication of flammability used in the Netherlands and Belgium, according to flashpoint: <ul style="list-style-type: none"> <li>• K1: &lt;21 °C</li> <li>• K2: 21 – 55 °C</li> <li>• K3: &gt;55 °C</li> </ul>
L	
LCA	life cycle assessment
LCCC	Low-cost conversion concept
LEL	lower explosion level
LNG	liquefied natural gas
LP	low pressure
LWC	low weight coated
M	
MDF	medium density fibre (boards)
MEK	methyl ethyl ketone
MF	machine finished
MKM	an Environmental Costing Model (MilieuKostenModel), see Annex 21.3.2

Glossary

ENGLISH TERM	MEANING
monitoring	process intended to assess or to determine the actual value and the variations of an emission or another parameter, based on procedures of systematic, periodic or spot surveillance, inspection, sampling and measurement or other assessment methods intended to provide information about emitted quantities and/or trends for emitted pollutants
MS	Member State of the European Union
N	
n/a	not applicable OR not available (depending on the context)
NC	nitrocellulose
n/d	no data
NEOE	non-easy-open ends
NF	nanofiltration
NIR	near infrared
NMP	n-methyl-pyrrolidone
NMVOC	non-methane volatile organic compound (see VOC)
NP/NPE	Nonylphenol and Nonylphenol Ethoxylates
NR	natural rubber
O	
oblongs	from can-making: refers to the shape of a general line container where the top and bottom ends are rectangular in shape with rounded corners
ODP	ozone depletion potential: a relative index indicating the extent to which a compound may cause ozone depletion
OEL	occupational exposure limit
OEM	original equipment manufacturer
OFP	ozone-forming potential
operator	any natural or legal person who operates or controls the installation or, where this is provided for in national legislation, to whom decisive economic power over the technical functioning of the installation has been delegated
OSPAR Convention	1992 OSPAR Convention is the instrument for the protection of the marine environment of the North Atlantic
ozone depletion	destruction of the stratospheric ozone layer, which can be caused by the photolytic breakdown of certain compounds containing chlorine and/or bromine (e.g. chlorofluorocarbons), which catalytically decompose ozone molecules
P	
PA	polyamide
PAH	polycyclic aromatic hydrocarbons
PARCOM	1974 Paris Commission on land based sources of marine pollution. Now superseded by the OSPAR Convention.
PBTs	persistent, bioaccumulative and toxic substances
PCP	pentachlorophenol
PE	polyethylene (polythene)
PET	polyethylene terephthalate
PI	process-integrated
PID	proportional integral derivative
POCP	photochemical ozone creation potential
pollutant	individual substance or group of substances which can harm or affect the environment
PM <sub>2.5</sub>	particulate matter with an aerodynamic diameter less than or equal to a nominal 2.5 micrometres
POP	persistent organic pollutants
PP	polypropylene
ppb	parts per billion
ppm	parts per million (by weight)
pre-product	a workpiece that is not the final product, but is treated and coated separately. In this document, for example, flat sheets that may be coated and/or printed prior to shaping and adding end pieces to form a can.
primary measure/technique	a technique that in some way changes the way in which the core process operates thereby reducing raw emissions or consumption (see end-of-pipe technique)

ENGLISH TERM	MEANING
PS	polystyrene
PTFE	polytetra fluoro ethylene
PU or PUR	polyurethane
PVA (or PVAC)	polyvinyl acetate
PVB	polyvinyl butyrate
PVC	polyvinyl chloride
PVdF (or PVF <sub>2</sub> )	polyvinylidene difluoride
PVF	polyvinyl fluoride
Q	
R	
RA	rate of evaporation
RAINS	Regional Air Pollution Information and Simulation for Europe. See Annex 21.3.1. Where RAINS is referred to in this document, it is RAINS version CP_CLE_Aug04(Nov04) For a review of data used in the RAINS-VOC model: <a href="http://www.iiasa.ac.at/web-apps/tap/RainsWeb/">http://www.iiasa.ac.at/web-apps/tap/RainsWeb/</a>
REACH	the EC's proposed new regulatory framework for the registration, evaluation and authorisation of chemicals. See: <a href="http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm">http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm</a>
reference conditions	from standard text – See Chapter 21
RH	relative humidity
right first time	production management quality control technique to enable product quality to be correct within a minimum number of completed items
ROI	return on investment
rto, RTO	regenerative thermal oxidation
S	
SB	solvent-based
SBR	butadiene styrene copolymer
SBS	styrene butadiene styrene (block copolymer)
SCR	selective catalytic reduction
secondary measure/technique	see end-of-pipe technique
IED	Directive 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 November 2010 on industrial emissions (integrated pollution prevention and control)
SIS	styrene isoprene styrene (block copolymer)
SME	small and medium enterprise(s)
SNCR	selective non catalytic reduction
SOMO 35	Statistical term: sum of means over 35
specific emission	emission related to a reference basis, such as production capacity, or actual production (e.g. mass per tonne or per unit produced)
STP	standard temperature and pressure
T	
TBT	tributyltin
TCF	totally chlorine-free
TDS	total dissolved solids
TGIC	triglycidyl isocyanurate: a mutagenic substance used in powder coatings
TLV	threshold limit values: guidelines (not standards) prepared by the American Conference of Governmental Industrial Hygienists, Inc (ACGIH) to assist industrial hygienists in making decisions regarding safe levels of exposure to various hazards found in the workplace. A TLV® reflects the level of exposure that the typical worker can experience without an unreasonable risk of disease or injury. TLVs® are not quantitative estimates of risk at different exposure levels or by different routes of exposure
TOC	total organic carbon: a test to assess the amount of organic carbon in a sample
TPB	triphenylborane
TPM	total production management
TWG	technical working group
U	

## Glossary

ENGLISH TERM	MEANING
UF	ultrafiltration
UF	urea formaldehyde
UNO	United Nations Organisation
UP	unsaturated polyester
UV	ultraviolet
V	
Varnish	Varnishes are preparations consisting of resinous matter dissolved in an oil or in solvent or other volatile liquid. When applied to the surface of wood, metal, etc., it dries and leaves a hard, more or less glossy, usually transparent coating.
VCA	vegetable cleaning agents
VHR	vapour hazard ratio
VOC	volatile organic compounds (see NMVOC)
vp or VP	vapour pressure
W	
waste gas	in this document, the IED definition is used: means the final gaseous discharge containing volatile organic compounds or other pollutants from a stack or abatement equipment into air;
WFD	Water Framework Directive: Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy.
WGT	Waste gas treatment
white spirit	CAS No: 8052-41-3. Also known as mineral spirits, high flash naphtha, petroleum distillate fractions, Stoddard solvent, petroleum distillates. Used as a paint thinner, a degreaser and a cleaning agent. It is a mixture of saturated aliphatic and alicyclic C7-C12 hydrocarbons with a content of 15-20 % (by weight) of aromatic C7-C12 hydrocarbons and a boiling range of 130 – 230 °C. The C9-C11 hydrocarbons (aliphatics, alicyclics and aromatics) are most abundant, constituting >80 % (by weight) of the total. Flashpoint (fp) and boiling point (initial, bp) according to grade: <ul style="list-style-type: none"> <li>• low flash grade: fp 21 - 30 °C, bp 130 - 144 °C</li> <li>• regular flash grade: fp 31 - 54 °C, bp 145 - 174 °C</li> <li>• high flash grade: fp =&gt;55 °C, bp 175 - 200 °C</li> </ul> [136, WHO_IPCS, 1996]
WHO	World Health Organisation
WW	winding wire
WWF	World Wildlife Fund
WWTP	waste water treatment plant
X	
Y	
Z	
DEHP	Bis(2-ethylhexyl) phthalate



## WPC GLOSSARY

The glossary provides information on abbreviations and specific terms used in the questionnaire. The definitions of terms in this glossary are not legal definitions (even if some of them may coincide with the definitions given in European legislation); they are meant to help the reader understand key terms in the context of their use in the questionnaire.

BAT	<p>Best available technique: as per Article 3(10), Chapter 1 of the Directive 2010/75/EU on industrial emissions (IED) "best available technique" means the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent, and, where this is not practicable, to reduce emissions and the impact on the environment as a whole.</p> <p>"Techniques" includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;</p> <p>"available" means developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;</p> <p>"best" means most effective in achieving a high general level of protection of the environment as a whole.</p>
BAT candidate(s)	<p>BAT candidates are 'Technique(s) to consider in the determination of BAT'. The information on 'Techniques to consider in the determination of BAT' is crucial in developing BAT conclusions. It will provide a catalogue of techniques (i.e. the technology used and the way in which the installations are designed, built, maintained, operated and decommissioned) and associated monitoring used for:</p> <ul style="list-style-type: none"> <li>— preventing emissions to air, water (including groundwater) and soil or, where this is not practicable, for reducing emissions,</li> <li>— preventing or reducing waste generation.</li> </ul> <p>The techniques described in the BREF will cover those which reduce the use of raw materials, water and energy, as well as measures used to prevent or to limit the environmental consequences of accidents and incidents and site remediation measures. They will also cover measures taken to prevent or reduce pollution under other than normal operating conditions (such as start-up and shutdown operations, leaks, malfunctions, momentary stoppages and the definitive cessation of operations).</p>
BATIS	The EIPPCB's BAT information system for the TWGs, used to share information within technical working groups.
Benzene	Organic chemical compound with the chemical formula C <sub>6</sub> H <sub>6</sub> .
Biocidal product(s)	Any substance or mixture, in the form in which it is supplied to the user, consisting of, containing or generating one or more active substances, with the intention of destroying, deterring, rendering harmless, preventing the action of, or otherwise exerting a controlling effect on, any harmful organism by any means other than mere physical or mechanical action (refer to Directive 98/8/EC of 16 February 1998 concerning the placing of biocidal products on the market).

## Glossary

Blue stain	According to CEN standard EN 1001-2 (August 2005): stain caused by fungi in which the discoloration ranges from pale blue to black. Usually affects the sapwood of certain species.
Blue stain in service	According to CEN standard EN 1001-2 (August 2005): staining of the sapwood of timber in service as a result of the growth of fungi with pigmented hyphae within the wood cells.
Blue stain treatment	Treatment to protect against blue stain (see above).
BREF	BAT Reference Document (resulting from the information exchange carried out for the activities in IED Annex I).
C	Abbreviation used for creosote (plant).
CAS number	A unique numerical identifier assigned by the Chemical Abstracts Service (CAS) to every chemical substance, organic or inorganic, e.g. 872-50-4 (for NMP). It will be found on SDSs (safety data sheets) to clearly identify substances.
Chemicals used in wood preservation or solvents	Chemicals used in wood preservation comprise biocides and the corresponding carrier chemicals (water, solvents or creosote), but also chemicals used for waterproofing (e.g. oils, emulsions, etc.), fire retardants and chemicals used in chemical wood modification (CWM) or hydrophobisation (like acetic anhydride, furfuryl alcohol, silicones) = treatment chemicals
CMR (substance)	Substances classified as carcinogenic, mutagenic or toxic to reproduction carrying the hazardous statements H340, H341, H350, H351, H360 or H361 (categories 1A, 1B or 2); refer to Regulation (EC) No 1272/2008 on Classification, Labelling and Packaging of substances and mixtures (CLP)
CMR-VOC	Substances or mixtures which, because of their content of volatile organic compounds classified as carcinogens, mutagens, or toxic to reproduction under Regulation (EC) No 1272/2008, are assigned or need to carry the hazard statements H340, H350, H350i, H360D, H360F or halogenated VOC which are assigned or need to carry the hazard statements H341 or H351. (Refer also to IED Art. 58 and IED, Annex VII, Part 4).
CO	Carbon monoxide.
Composite sample	Two or more samples or spot samples (either discretely or continuously) mixed/blended together in appropriate known proportions from which the average result of a desired characteristic may be obtained.
Containment	(also referred to as secondary containment), a concrete-lined, impermeable pit or basin for collecting liquid spills and leakages.
Continuous measurement/Continuous monitoring	Continuous measurement is defined as measurements made with an automated measuring system (AMS) permanently installed on site for the continuous monitoring of emissions (according to EN 14181).
Diffuse emissions	Non-channelled emissions to the environment. Emissions usually concern volatile or dusty substances. Diffuse emission sources can be point, linear, surface or volume sources. Examples include storage facilities during loading and unloading, open-air storage, opening of autoclave (treatment vessel) doors, non-enclosed/non-covered chemical treatment vessels. Multiple emissions inside a building are normally considered diffuse emissions.

Drip tray	Tray or pan-like devise for collection of spills and drippage.
El	Electrical.
FID	Flame ionisation detector (used for measuring VOCs in waste gas streams).
Fugitive emissions (in the context of SMP and SMB only)	Fugitive emissions means any emissions not in waste gases of volatile organic compounds into air, soil and water as well as solvents contained in any products, unless otherwise stated in Part 2 of Annex VII to the IED ('Solvent management plan').
HOI	Total hydrocarbon oil index content (HOI).
IED	Industrial Emissions Directive 2010/75/EU. Directive which requires the EC to carry out an information exchange to determine BAT for the relevant industries, including this questionnaire data collection exercise.
Installation	Stationary technical unit within which one or more activities listed in Annex I to Directive 2010/75/EU are carried out and any other directly associated activities on the same site which have a technical connection with an activity listed in Annex I and which could have an effect on emissions and pollution.
LoD Limit of detection	The output signal or concentration value above which it can be affirmed with a stated level of confidence that a sample is different from a blank sample containing no determinant of interest.
LoQ Limit of quantification	A stated multiple of the limit of detection at a concentration of the determinant that can reasonably be determined with an acceptable level of accuracy and precision. The limit of quantification can be calculated using an appropriate standard or sample, and may be obtained from the lowest calibration point on the calibration curve, excluding the blank.
MS	Member State
Naphthalene	Organic compound with formula C <sub>10</sub> H <sub>8</sub> . It is the simplest polycyclic aromatic hydrocarbon.
Nm <sup>3</sup>	Unit of volume at standard conditions – temperature of 273.15 K and pressure of 101 325 Pa.
Normal operating conditions (NOC)	<p>The conditions during which the plant is operating and discharging emissions into the air, excluding other than normal operating conditions.</p> <p>The conditions during which a WPC plant is operating and releasing emissions into the air and/or water, excluding other than normal operating conditions. Please note that normal operating conditions may include operation with higher load factors (i.e. closer to nominal load factor), as well as lower load factors (i.e. closer to minimal load), depending on the installation demand/design.</p>
NO <sub>x</sub>	Nitrogen oxide.
NP (1 - 6)	Penetration class as defined in EN 351 (Classification of preservative penetration and retention). EN 351 establishes classification for preservative-treated wood in terms of preservative penetration and gives guidance on a classification of retention. These can be used as a basis for specifying preservative treatments for particular products.

## Glossary

Operating hours	The hours during which a WPC plant is operating.
Organic solvent	Any volatile organic compound which is used for any of the following: (a) alone or in combination with other agents, and without undergoing a chemical change, to dissolve raw materials, products or waste materials; (b) as a cleaning agent to dissolve contaminants; (c) as a dissolver; (d) as a dispersion medium; (e) as a viscosity adjuster; (f) as a surface tension adjuster; (g) as a plasticiser; (h) as a preservative.
Other than normal operating conditions (OTNOC)	Article 14 (f) of the IED refers to other than normal operating conditions as start-up and shutdown operations, leaks, malfunctions, momentary stoppages and definitive cessation of operations.
PAH	Polycyclic aromatic hydrocarbon.
Periodic measurement/ Periodic monitoring	A sampling campaign in which, during a predefined period of time (e.g. half an hour, 1 hour, 6 hours), a parameter is analysed continuously (i.e. the 'final' value is calculated as the average of the whole data set obtained during the period). This may also be understood as the analysis of a composite sample taken continuously over a period of time. The corresponding uncertainty is considered to be either the uncertainty of the measurement method or 4 s of the sampling campaign, whichever is larger.
Plant	A segment/part of an installation in which a specific processing operation is conducted (refer also to WPC plant).
Priority substances (PS)	Substances listed in Annex X to Directive 2000/60/EC.  Substances or groups of substances, presenting a significant risk to or via the aquatic environment, including industrial chemicals, plant protection products, biocides, metals and other groups like Polyaromatic Hydrocarbons (PAH) that are mainly incineration by-products and Polybrominated Biphenylethers (PBDE) that are used as flame retardants.  <i>(refer to "Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy", i.e. the EU Water Framework Directive (WFD))</i>
Product	Product refers to the 'output' of a WPC plant, i.e. the treated wood/wood product/commodity. For the purpose of this questionnaire, treated wood/wood product/commodity is shortened: 'treated wood'.  Please note that 'the volume of treated wood', e.g. where the questionnaire asks for 'specific data' (specific consumption, specific emission etc.), refers to the volume of wood product (sellable product) and not just the impregnated portion of the wood product.
PS	Priority substances ( <i>see also above</i> ).
Sap stain	According to CEN standard EN 1001-2 (August 2005): discolouration of wood resulting from the growth of micro-fungi which derive their nourishment from cell contents but do not cause significant decomposition of the wood. Its development is principally confined to the sapwood of green timber (freshly felled timber).

Sap stain treatment	Protective treatment of a temporary nature given to green timber against sap-staining fungi.
SB	Abbreviation used for solvent-based.
SMB	Solvent mass balance.
SMP	Solvent management plan (Part 2 of Annex VII to the IED).
Solvent management plan (SMP) & Solvent mass balance (SMB)	Solvent Management Plan is a mass balance of the VOC solvents used in and emitted from an installation using organic solvents. Part 7 of Annex VII to the IED.
'Specific' data (e.g. specific consumption)	Refers to data, e.g. consumption (in kg, m <sup>3</sup> ) per volume of 'product' of the WPC plant ( $\Rightarrow$ kg/m <sup>3</sup> or m <sup>3</sup> /m <sup>3</sup> treated wood).
Spot sample	Sample taken from the sampling point at a certain time over a particular period.
Start-up and shutdown operations	Operations excluding regularly oscillating activity phases whilst bringing an activity, an equipment item or a tank into or out of service or into or out of an idling state.
Substances of very high concern	Substances that have been proposed to be subject to authorisation (e.g. to be included in Annex XIV) under the REACH Regulation. According to Article 57, these may be substances that are: CMR (category 1A or 1B), PBT (persistent, bioaccumulating, and toxic), vPvB (very persistent and very bioaccumulating), or of equivalent level of concern, ELoC (endocrine disrupting). <i>(refer to Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH))</i>
Surface run-off water	Surface run-off water is generated by rain, snowmelt or cleaning events; it is the water that flow over land or impervious surfaces, such as paved streets and storage areas, rooftops etc. and does not soak into the ground. It can, in exceptional cases (OTNOC), comprise firefighting water as well.
SVHC	Substances of very high concern <i>(see also above)</i>
Treatment vessel	
'Technique(s) to consider in the determination of BAT'	See BAT candidates.
Th	Thermal.
TOC	Total organic carbon.
Treatment area (=working area DE ?)	The treatment area consists of the treatment vessels, working vessels, associated pipework, treatment vessel loading area consisting of the full rail line (and or assess for ways for vehicles, cane loading /handling area) and post-treatment drying area.
Treatment facility	A brushing or a spraying device used for preservative treatment.
Treatment vessel	A dipping tank, a deluging tank or an autoclave used for preservative treatment.
TWG	Technical working group, consisting of technical experts representing Member States, industries, non-governmental organisations (NGOs) and the Commission, in charge of drawing up or reviewing BREF documents.
UC (1 - 5)	Use class as defined in EN 335. EN 335 defines five use classes which represent different service situations to which wood and wood-based products can be exposed.
VOC	Volatile organic compound.

## Glossary

Volatile organic compound	For the IED, 'volatile organic compound' means any organic compound, as well as the fraction of creosote, having at 293.15 K a vapour pressure of 0.01 kPa or more, or having a corresponding volatility under the particular conditions of use.
vol-%	Volume percent.
Waste	According to the definition in Directive 2008/98/EC: Any substance or object which the holder discards or intends or is required to discard.
Waste gas	The final gaseous discharge containing volatile organic compounds or other pollutants from a stack or abatement equipment into air.
WB	Abbreviation used for water-based.
Wood moisture	Mass of water in wood/mass of dry wood * 100 [%]
Wood preservation	For the purpose of the WPC parts of the STS BREF (and thus for this WPC questionnaire), wood preservation refers to activities with the purpose of protecting wood and wood products from the damaging effects of fungi, bacteria, insects, water, weather or fire; providing long-term conservation of structural integrity and improving the resistance of wood and wood products (i.e. treatments such as impregnation with oil or wax and blue stain treatment are included).
WPC plant/ Wood preservation plant	A stationary technical unit and equipment dedicated to the preservation of wood or wood products with chemicals. A WPC plant may include one or several treatment lines.
Working vessel	Intermediate storage vessel for preservative solution in pressure processes. Preservative feeds from the bulk tank or containers to the working vessel, and from there into the treatment vessel.
wt-%	Weight percent
WW	Waste water
WWT(P)	Waste water treatment (plant)

## Common units, measurements and symbols

TERM	MEANING
atm	normal atmosphere (1 atm = 101325 N/m <sup>2</sup> )
bar	bar (1.013 bar = 1 atm)
billion	thousand million (10 <sup>9</sup> )
°C	degree Celsius
cm	centimetre
d	day
g	gram
GJ	gigajoule
h	hour
J	Joule
K	kelvin (0 °C = 273.15 K)
kcal	kilocalorie (1 kcal = 4.19 kJ)
kg	kilogram (1 kg = 1000 g)
kJ	kilojoule (1 kJ = 0.24 kcal)
kPa	kilopascal
kt	kilotonne
kWh	kilowatt-hour (1 kWh = 3600 kJ = 3.6 MJ)
l	Litre
m	metre
m <sup>2</sup>	square metre
m <sup>3</sup>	cubic metre
mg	milligram (1 mg = 10 <sup>-3</sup> gram)
MJ	megajoule (1 MJ = 1000 kJ = 10 <sup>6</sup> joule)
mm	millimetre (1 mm = 10 <sup>-3</sup> m)
m/min	metres per minute
Mt	megatonne (1 Mt = 10 <sup>6</sup> tonne)
Mt/yr	megatonnes per year
mV	millivolts
MW <sub>e</sub>	megawatts electric (energy)
MW <sub>th</sub>	megawatts thermal (energy)
ng	nanogram (1 ng = 10 <sup>-9</sup> gram)
Nm <sup>3</sup>	normal cubic metre (101.325 kPa, 273 K)
Pa	pascal
ppb	parts per billion
ppm	parts per million (by weight)
ppmv	parts per million (by volume)
s	second
t	metric tonne (1000 kg or 10 <sup>6</sup> gram)
t/d	tonnes per day
trillion	million million (10 <sup>12</sup> )
t/yr	tonne(s) per year
V	volt
v/v	volume/volume, usually expressed as a percentage and is the same as vol-%
vol-%	percentage by volume (Also % v/v)
W	watt (1 W = 1 J/s)
w/w	weight/weight, usually expressed as a percentage and is the same as vol-%
wt-%	percentage by weight (Also % w/w)
yr	year
μ	
μm	micrometre (1 μm = 10 <sup>-6</sup> m)
μS	micro siemens

## List of chemical elements

NAME	SYMBOL	NAME	SYMBOL
actinium	Ac	mercury	Hg
aluminium	Al	molybdenum	Mo
americium	Am	neodymium	Nd
antimony	Sb	neon	Ne
argon	Ar	neptunium	Np
arsenic	As	nickel	Ni
astatine	At	niobium	Nb
barium	Ba	nitrogen	N
berkelium	Bk	nobelium	No
beryllium	Be	osmium	Os
bismuth	Bi	oxygen	O
boron	B	palladium	Pd
bromine	Br	phosphorous	P
cadmium	Cd	platinum	Pt
calcium	Ca	plutonium	Pu
californium	Cf	polonium	Po
carbon	C	potassium	K
cerium	Ce	praseodymium	Pr
caesium	Cs	promethium	Pm
chlorine	Cl	protactinium	Pa
chromium	Cr	radium	Ra
cobalt	Co	radon	Rn
copper	Cu	rhenium	Re
curium	Cm	rhodium	Rh
dysprosium	Dy	rubidium	Rb
einsteinium	Es	ruthenium	Ru
erbium	Er	rutherfordium	Rf
europium	Eu	samarium	Sm
fermium	Fm	scandium	Sc
fluorine	F	selenium	Se
francium	Fr	silicon	Si
gadolinium	Gd	silver	Ag
gallium	Ga	sodium	Na
germanium	Ge	strontium	Sr
gold	Au	sulphur	S
hafnium	Hf	tantalum	Ta
helium	He	technetium	Tc
holmium	Ho	tellurium	Te
hydrogen	H	terbium	Tb
indium	In	thallium	Tl
iodine	I	thorium	Th
iridium	Ir	thulium	Tm
iron	Fe	tin	Sn
krypton	Kr	titanium	Ti
lanthanum	La	tungsten	W
lawrencium	Lr	uranium	U
lead	Pb	vanadium	V
lithium	Li	xenon	Xe
lutetium	Lu	ytterbium	Yb
magnesium	Mg	yttrium	Y
manganese	Mn	zinc	Zn
mendelevium	Md	zirconium	Zr



## SI unit prefixes

Symbol	Prefix	Term	Number
Y	yotta	$10^{24}$	1 000 000 000 000 000 000 000 000
Z	zeta	$10^{21}$	1 000 000 000 000 000 000 000
E	exa	$10^{18}$	1 000 000 000 000 000 000
P	peta	$10^{15}$	1 000 000 000 000 000
T	tera	$10^{12}$	1 000 000 000 000
G	giga	$10^9$	1 000 000 000
M	mega	$10^6$	1 000 000
k	kilo	$10^3$	1000
h	hecto	$10^2$	100
da	deca	$10^1$	10
-----	-----	1 unit	1
d	deci	$10^{-1}$	0.1
c	centi	$10^{-2}$	0.01
m	milli	$10^{-3}$	0.001
$\mu$	micro	$10^{-6}$	0.000 001
n	nano	$10^{-9}$	0.000 000 001
p	pico	$10^{-12}$	0.000 000 000 001
f	femto	$10^{-15}$	0.000 000 000 000 001
a	atto	$10^{-18}$	0.000 000 000 000 000 001
z	zepto	$10^{-21}$	0.000 000 000 000 000 000 001
y	yocto	$10^{-24}$	0.000 000 000 000 000 000 000 001

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